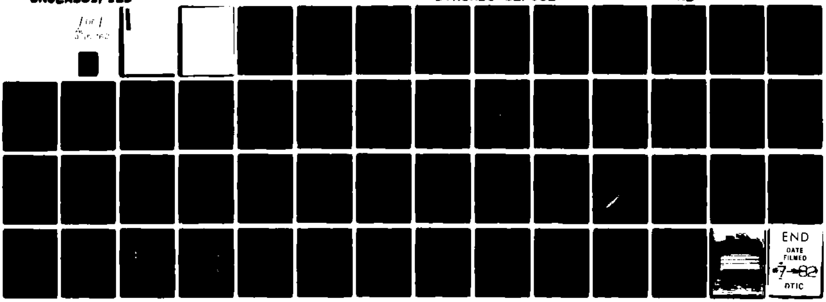
AD-A115 762 KUHN (RICHARD E) NEWPORT NEWS VA F/G 1/2
HIGH PRESSURE BLEED FOR STOL AND STO-VL PERFORMANCE - A CONCEPT--ETC(U)
MAY 82 R E KUHN N00167-81-M-3207

UNCLASSIFIED DTNSRDC-82/032 NL



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER DTNSRDC-82/032	2. GOVT ACCESSION NO. AD-A115762	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HIGH PRESSURE BLEED FOR STOL AND STO-VL PERFORMANCE -- A CONCEPTUAL EXAMINATION		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER Aero Report 1279
7. AUTHOR(s) Richard E. Kuhn		8. CONTRACT OR GRANT NUMBER(s) N00167-81-M-3207
9. PERFORMING ORGANIZATION NAME AND ADDRESS Richard E. Kuhn, Inc. V/STOL Consultant Newport News, Virginia 23606		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Work Unit 1600-001
11. CONTROLLING OFFICE NAME AND ADDRESS David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084		12. REPORT DATE May 1982 13. NUMBER OF PAGES 51
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

V/STOL, STOL, STO-VL, Jet Flap, Bleed Air, Lift Fan

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The engines in modern combat aircraft are sized by combat maneuverability considerations. These aircraft therefore have much more thrust available than is needed at normal takeoff and landing speeds. Only the Harrier, which can vector the thrust of the centrally-mounted engine through the center of gravity can use its excess thrust to reduce the takeoff and landing distance (to zero at low operating weights). The engines on the

(Continued on reverse side)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(Block 20 continued)

others are too far aft for direct thrust vectoring. This paper examines other possibilities. The main emphasis is on the possibility of using bleed air from the high pressure compressor to blow the wing and/or a canard for STOL performance. Alternately, the use of this high pressure bleed to drive fold-out fans to achieve STO-VL performance is also examined.

TABLE OF CONTENTS

LIST OF FIGURES

NOTATION

A	Duct area, ft^2
C_D	Drag coefficient
C_L	Lift coefficient
C_M	Jet flap momentum coefficient
D	Drag, lb
L	Lift, lb
m	Mass flow, slugs/sec
P	Total pressure, lb/ft^2
S	Wing area, ft^2
T	Thrust, lb
t	Total temperature, R
V	Velocity, ft/sec
V_2	Takeoff velocity, ft/sec
W	Weight, lb
α	Angle of attack, deg
δ	Jet deflection, deg

Subscripts

a	Atmospheric
b	Bleed
e	Engine
f	Fan
j	Jet
o	Nozzle
r	Sea level-static thrust rating of engine

METRIC CONVERSION TABLE

American Standard	Metric
1 foot	0.3048 m
1 pound	0.4536 kg
1 slug	14.59 kg

ABSTRACT

The engines in modern combat aircraft are sized by combat maneuverability considerations. These aircraft therefore have much more thrust available than is needed at normal takeoff and landing speeds. Only the Harrier, which can vector the thrust of the centrally-mounted engine through the center of gravity can use its excess thrust to reduce the takeoff and landing distance (to zero at low operating weights). The engines on the others are too far aft for direct thrust vectoring. This paper examines other possibilities. The main emphasis is on the possibility of using bleed air from the high pressure compressor to blow the wing and/or a canard for STOL performance. Alternately, the use of this high pressure bleed to drive fold-out fans to achieve STO-VL performance is also examined.

ADMINISTRATIVE INFORMATION

This study was completed for the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) under Navy contract N00167-81-M-3207. Mr. Kuhn was engaged in V/STOL (vertical and/or short takeoff and landing) aircraft research with the NASA Langley Research Center for many years. He now serves as a V/STOL consultant to both industry and the Government.

INTRODUCTION

Design studies of V/STOL aircraft show that requiring VTOL performance results in a large weight penalty relative to CTOL (Conventional) aircraft. However, the only V/STOL aircraft that has been put into service, the Harrier, is seldom operated in the VTOL mode. Instead, it is usually operated in the STO-VL mode; using a short takeoff run to lift-off much greater loads than it could in a vertical takeoff, and return to a vertical landing at the end of the mission. In this STO-VL mode of operation the penalty for short field operation is relatively small, as shown in Figure 1.

The empty weight, the design or normal takeoff weight, and the maximum overload takeoff weight of several fighter and attack aircraft, including the AV-8A and AV-8B versions of the Harrier, are compared in Figure 1. The maximum useful load (taken as the difference between the maximum overload takeoff weight and the empty weight) of the Harriers is the lowest of those compared. However, the Harriers are also the

smallest and lightest aircraft. When the ratio of the useful load to empty weight (a rough measure of the job that can be done per pound of aircraft required to do it) are compared, the Harriers (particularly the AV-8B which has the improved wing-flap-nozzle arrangement) are comparable to the CTOL aircraft. And the Harrier requires only one-half to one-fourth the takeoff distance needed by conventional aircraft at the maximum takeoff weight.

The Harrier achieves this performance by virtue of the high installed thrust which can be deflected to add to the wing lift for takeoff. The F-15, F-16, and F-18 also have considerable excess thrust at takeoff conditions, but the arrangement of the aircraft precludes direct use of this excess thrust to lower the takeoff speed and improve takeoff performance. In this class of aircraft, the need for supersonic performance and good transonic maneuverability argue against placing the engine at the center of the aircraft so that the thrust can be vectored through the center of gravity.

This paper attempts to illustrate the principal factors that contribute to the good short field performance of the vectored thrust Harrier STO-VL aircraft and to examine alternate approaches that could be used to achieve STOL and STO-VL performance without placing the engine at the center of the aircraft.

TAKEOFF PERFORMANCE

THRUST VECTORING FOR SHORT TAKEOFF

The Harrier makes its takeoff run with the jets undeflected until the takeoff speed is reached. At this speed the nozzles are rotated to a predetermined deflection and the vertical component of thrust adds to the aerodynamic wing lift to achieve lift-off. A vector diagram of the lift, drag, and thrust components at lift-off speed is shown in Figure 2. The jet deflection is chosen such that the horizontal component of the gross thrust, $T \cos \delta$, equals the sum of the inlet and aerodynamic drag plus an allowance for acceleration and/or climb. The lift is the sum of the vertical component of thrust, the aerodynamic lift and the jet induced lift (which is negative on the AV-8A, but is almost zero on the AV-8B).

The relative magnitude of these components and their variation with speed are shown in Figure 3 for the AV-8B at its maximum takeoff weight of 29,550 lb. The

large amount of excess thrust and the large contribution of the thrust to lift are evident. Without the ability tc deflect the thrust, the only contribution of thrust to lift would be the smaller increment given by T sin α. By deflecting the thrust about 60 deg the takeoff speed is reduced about 40 percent.

A similar presentation for the F-18 is presented in Figure 4. Even at its maximum overload takeoff weight of 47,000 lb, the F-18 has almost as much excess thrust as the AV-8B, but the potential reduction in takeoff speed cannot be realized because the thrust cannot be vectored through the center of gravity.

The takeoff ground runs are compared in Figure 5. Without vectoring, the takeoff distance of the AV-8B would be about three times the approximately 1200 ft that can be achieved with vectoring. The takeoff speed of the F-18 is lower than that for the AV-8B without vectoring because the F-18 is taking off at a lower wing loading and has a more sophisticated high lift system.

A brief examination of the thrust, drag, and lift variations with takeoff speed for other modern fighter aircraft at their maximum overload takeoff weights shows that they all have similar characteristics; see Figure 6. And they all have large excess thrust and potentially lower takeoff speeds; even lower than the AV-8B because they are operating at lower wing loadings and have more sophisticated high lift systems. Unfortunately these lower takeoff speeds, and the shorter takeoff distances that would result, cannot be realized because the thrust cannot be vectored through the center of gravity. Other methods of using this excess thrust to lower the takeoff speed should be investigated.

ALTERNATE APPROACHES TO SHORT TAKEOFF PERFORMANCE

The engines in modern fighter aircraft are installed aft in order to control the area distribution of the configuration and minimize wave drag so that good transonic maneuverability and supersonic performance can be achieved. The thrust can only be deflected downward to contribute to lift if a corresponding lift force can be generated forward of the center of gravity to balance the nosedown moment due to deflecting the thrust at the rear. Possibilities include a nose jet or a jet flap canard as illustrated in Figure 7. Bleeding the engines to power a nose jet or a jet flap canard would reduce the thrust but, as shown in Figures 4 and 6, there is considerable excess thrust available; part of the excess can be used for bleed and part for thrust deflection.

As the takeoff speed is reduced, the control that can be obtained from conventional surfaces reduces and must be augmented. The Harrier has a hovering control system (control jets at the extremities of the airplane) that provides this augmentation. As shown in Figure 7, the present study assumes that this control augmentation would be achieved by additional vectoring of the main nozzle thrust.

The effect of bleed on the engine thrust and bleed pressure used in this study is shown in Figure 8. The lapse rate, shown here, is an extrapolation of information on the effects of small bleed rates (less than 5 percent). It has been suggested that the effect of bleed can be reduced by using variable area turbines or turbine bypass features,[1*] however, generalized data that could be used in a study of this type are not available. Also, these features would essentially require developing a new engine. Bleed rates assumed in the present study may be possible with existing engines, but would require modification and requalification of the engine.

The thrust available from bleed air and the duct area required are presented in Figure 9. Duct losses of 35 percent of the total pressure and 20 percent of the total temperature are assumed. The aerodynamic characteristics used in the analysis of the takeoff performance are shown in Figures 10 and 11. The canard is assumed to have the same planform as the wing and to have one-fourth the area.

The effect of a nose jet alone (canard off) on the takeoff speed is shown in Figure 12. As the bleed air taken from the engine is increased, the nose jet thrust increases and the deflection of the primary jet that can be balanced by the nose jet increases. However, the net thrust, after the effects of bleed and jet deflection are accounted for, reduces. Takeoff speed is defined as the speed at which the total lift equals the weight (T/W=1.0) and an acceleration allowance of at least 0.05 g's (D/W=0.05) can be maintained. This occurs with the nose jet alone on the present configuration at about 15 percent bleed. With the nose jet, the takeoff speed is reduced only about 8 or 9 knots. Fifteen percent bleed produces only about 2350 lb of thrust from the nose jet which requires deflecting the primary thrust only about 12 deg to balance. A method of greatly augmenting the lifting power produced by the bleed air is required if significant increases in jet deflection and reduction in takeoff speed are to be achieved.

---

*A complete listing of references is given on page 41.

At forward speeds the best way to augment jet thrust is to blow the jet over the surface of a lifting surface. A properly designed jet flap configuration can produce lift up to an order of magnitude greater than the jet thrust used.

The effect of using a jet flap canard surface on the present configuration is shown in Figure 13. Unfortunately, the canard cannot be placed as far forward as the nose jet, and the downwash from the canard acting on the wing produces a down load that reduces the net lift obtained from the canard. In this study it has been assumed that only one quarter of the lift of the isolated canard is realized as net canard lift, but that the full canard lift acts to produce a nose up moment to balance the nose down moment from the deflected main jet. Also the extra drag of the highly loaded jet flap canard must be included. With the jet flap canard, the bleed that can be used is reduced to about 8 percent, but the jet deflection that can be used is doubled and the takeoff speed is reduced about 25 knots.

Further gains can be made if bleed air is used to blow both the wing and the canard (Figure 14). As noted above, about three-quarters of the canard lift is lost due to the downwash of the canard on the wing. This large penalty is largely eliminated if most of the bleed air is used to blow the wing. However, a large part of the nose up moment produced by the canard is used to balance the diving moment from the jet flapped wing and the main jet deflection can only be about 10 deg. Nevertheless, the takeoff speed is reduced by about 35 knots.

One of the factors in the above studies that has made it difficult to achieve large jet deflections has been the far aft location of the engines. The effect of moving the engines forward is shown in Figure 15 and the configuration assumed is shown in Figure 16. Moving the engines forward approximately doubles the jet deflection that can be used and decreases the takeoff speed by an additional 6 to 8 knots.

A comparison of the takeoff distances required by each of the above configurations is presented in Figure 17. This work suggests that takeoff distances of high performance fighter configurations can be approximately halved by proper use of high pressure bleed air.

LANDING PERFORMANCE

The space required for landing an aircraft depends upon a number of variables. The primary factors are the touchdown speed (which depends upon the capability of the high lift system and on the wing loading of the airplane) and the deceleration (which depends upon the brakes and runway conditions, the drag of the airplane, and the amount of reverse thrust that can be achieved). In addition, the time delay in actuating the thrust reversers and in reducing the wing lift, the allowance that must be made for touchdown dispersion, and the length of the aircraft must be considered. Figure 18 presents a generalized presentation of the effects of these factors on the total landing distance.

The one-second delay used in Figure 18 assumes that an in-flight thrust reverser or some other technique is used so that the engine can be maintained at full RPM to minimize time lag in establishing thrust reversal. The one second allows for pilot reaction, brake and thrust reverser actuation, and switching off the bleed air to the blown flaps or other power augmentation of lift that may be used. The touchdown dispersion allowance is based on NASA experience with the upper surface blowing research airplane, the QSRA (Quiet STOL Research Airplane). Using a fresnel lens landing guidance system, a touchdown dispersion of $\pm$ 30 ft or less at an approach speed of about 65 knots was experienced.[3] The touchdown dispersion allowance used in Figure 18 was assumed to be proportional to the landing speed and to be double the QSRA experience at 65 knots in order to be conservative. An allowance of 50 ft was included for the aircraft to turn and taxi away at the end of the landing run.

The variation of lift and drag with landing speed for a conventional fighter (approximately the F-18) at maximum landing weight (based on the aerodynamic characteristics presented in Figure 19) are presented in Figure 20. The potential reduction in landing speed cannot be realized, of course, because the thrust cannot be vectored through the center of gravity.

A significant reduction in landing speed can be realized by using bleed-air powered jet flaps (Figure 21). The landing approach would be made at minimum afterburning power in order to keep the engine RPM up so that full bleed capability would be available to blow the flaps and so that time would not be required to spool up the engine to achieve good thrust reverser performance for the deceleration after

touchdown. The bleed air to the canard is double that used in takeoff, in order to increase the drag and decrease the net thrust. The latter is necessary to achieve the excess drag required for descent at the landing speed. The three-degree approach shown would result in a sink speed of about 7 ft per second at touchdown in a no-flare landing. Using minimum afterburner in the approach makes it possible to maintain maximum jet flap effectiveness and still be able to take a wave-off by going to full afterburner.

The landing performance shown in Figure 21 was estimated for a weight of 30,000 lb; nearly maximum landing weight. The effect of landing weight on the landing speeds is shown in Figure 22.

The use of powered lift can reduce the landing distance by almost half (Figure 23). The actual landing space required depends upon the deceleration that can be achieved. The deceleration on ice using brakes alone would be only about 0.1 g or less. The QSRA, using brakes alone on dry runways, has shown an average deceleration of about 0.3 g's. Decelerations of 0.5 g's or greater will require effective and fast acting thrust reversers.

LIFT FAN STO-VL CONFIGURATIONS

As indicated in the introduction, the Harriers are normally operated in the STO-VL mode; using a short takeoff run to lift large payloads and returning to a vertical landing at the end of the mission when the aircraft is lighter. They also retain the capability of carrying out reduced radius missions from a vertical takeoff when necessary.

The Harrier, however, is an attack, not an air superiority, aircraft. The performance and transonic maneuverability of modern fighters requires a higher fineness ratio configuration with the engine(s) moved further aft. However, a simple bleed-air jet at the nose is not sufficient to balance the deflected thrust of the main engines; it must be augmented. The best way to augment jet thrust at zero speed, and to retain a relatively cool front-end footprint, is to use the bleed air to drive a fan. Augmentation factors of four to five can be obtained with a fan.

A type of configuration envisioned is shown in Figure 24. Foldout fans (Figure 25) are mounted as far forward as possible and ADEN type nozzles are used on the engines to deflect the thrust to the vertical. Space considerations require

using relatively highly loaded two-stage fans. The data of Reference 4 were used to size the fans in the present conceptual study. In order to maximize the thrust that could be obtained with the limited fan diameter, an interburner was assumed that would raise the temperature of the air entering the tip turbine to the maximum value used in Reference 4, 1998 R. The estimated fan thrust is shown in Figure 26. The main jet thrust reduces with bleed rate but the total thrust of the system is increased (at the lower bleed rates at least) because the bypass ratio of the system has been increased.

Control in hovering is achieved by thrust transfer and thrust deflection. Pitch control is obtained by differential change of thrust between the fans and the main nozzles; increasing the fan thrust and decreasing the main nozzle thrust for nose up control and the reverse for nose down control. Variable inlet guide vanes would be required on the fans to obtain the response rates required and varying the inlet area to the fan tip turbine would be required to accommodate the change in bleed rate. Roll control would be obtained by diagonal transfer of thrust; having the right engine drive the left fan and the left engine drive the right fan, so that shifting thrust forward from the right engine to the left fan and rearward from the right fan to the left nozzle would give a rolling moment to the right, for instance. Figure 27 shows that, with the geometry of the configuration chosen for this example (Figure 24), the thrust shift required for roll control is greater than that required for pitch control. Roll control therefore sets the design point of the fan. Yaw control is obtained by differential lateral deflection of the thrust vectors of the fan and main nozzles.

The vertical takeoff and landing performance is presented in Figure 28. Installation losses include inlet, power takeoff and an allowance of 5 percent of the rear nozzle thrust for the 90-deg deflection. The ground effects were estimated by the method of Reference 6. In ground effect, the widespread four-poster arrangement of the fan and rear nozzle jet streams produce a favorable fountain effect between them that largely offsets the suckdown normally experienced in ground effect and more than compensates at the lowest heights. Hot-gas ingestion is minimized using a top inlet and by designing the strakes on the bottom of the fuselage to deflect the fountain flow laterlly as recommended in Reference 7.

The short takeoff performance at a maximum overload weight of 47,000 lb is estimated in Figure 29. Takeoff is made with the fans at a deflection of 60 deg; that is, with the fan thrust deflected 30 deg aft of the vertical, with the main nozzles undeflected (full aft), and at minimum fan thrust (minimum bleed) so as to maximize the main nozzle thrust and acceleration. At lift-off speed, the fan thrust is increased to rotate the aircraft to about 15 deg angle of attack and the main nozzles are deflected 48 deg to achieve lift-off. The main nozzles are located at the wing trailing edge to produce a favorable jet induced lift increment (Reference 8) that more than offsets the unavoidable lift loss induced by the fan flow. Takeoff speed is reduced to about 60 percent of that for the corresponding CTOL airplane. The takeoff distance is only about 30 percent of that for the CTOL (Figure 30) and a little over half that of the corresponding STOL concepts.

The lift fan STO-VL configuration has the penalty of the added weight and complexity of the lift fans, but this is partially offset by not having the thrust reversers and the jet flap system required for STOL.

CONCLUDING REMARKS AND SUGGESTIONS FOR ADDITIONAL WORK

This brief study has indicated that the takeoff and landing distance of high performance fighter class aircraft can be approximately halved by using jet flaps driven by high pressure compressor bleed air. Alternatively, if STO-VL performance is needed, compressor exit bleed can be used to drive fold-out lift fans to augment the deflected thrust of the primary nozzles. The bleed rates required are much greater than those for which engines are normally rated, however, Reference 9 suggests that these bleed rates can be achieved. The engines would have to be modified and requalified if these high bleed rates were to be used operationally.

The effect of bleed on the engine thrust and bleed pressure ratio used in this study is an extrapolation of information available at low bleed rates. The actual reduction in thrust at high bleed rates will depend upon the engine type and design. If the concepts suggested in this study are of interest and are to be pursued, further studies of specific candidate engines should be undertaken to obtain more accurate data on the effects of bleed on the engine performance and to determine the engine modifications and requalification program that would be required.

It has been suggested that the penalties of high bleed rates could be reduced by using new concepts such as variable area turbines or the turbine bypass. The development effort in applying these concepts is probably comparable to developing a new engine, but they should be investigated. Studies of engine concepts designed to provide large amounts of high pressure bleed air with minimum performance penalty should be undertaken to determine the cost and payoff of new technology engines relative to modifications of existing engines.

The sizing of the foldout fan used in the present study was based on the tip turbine fan study of Reference 4 which covered fan pressure ratios up to 1.7. Space limitations in fighter configurations require high fan pressure ratios, and the data of Reference 4 had to be extrapolated for the present study. Design studies similar to the study of Reference 4 of fan-engine systems suitable for STO-VL fighter configurations should be undertaken. The high fan pressure ratios required for fighter installations require high hub-to-tip radius ratios which suggest that a multiple stage hub turbine instead of the tip turbine may be used. The possibility that a hub turbine driven fan may package better in a fighter configuration than a tip turbine configuration should also be investigated.

The bleed air and high power levels used in STOL and STO-VL operation are only required for very short periods of time. The high power portions of takeoff and landing operations are measured in seconds rather than minutes. This circumstance is recognized in the Harrier operation and the engine is qualified to a special rating system. This should also be recognized in the above studies and special techniques for increasing the thrust and bleed rates for very short periods of time should be investigated. The studies should assume the the propulsion system will be rated on a special rating system similar to that used in the Pegasus engine used in the Harriers, Reference 10.

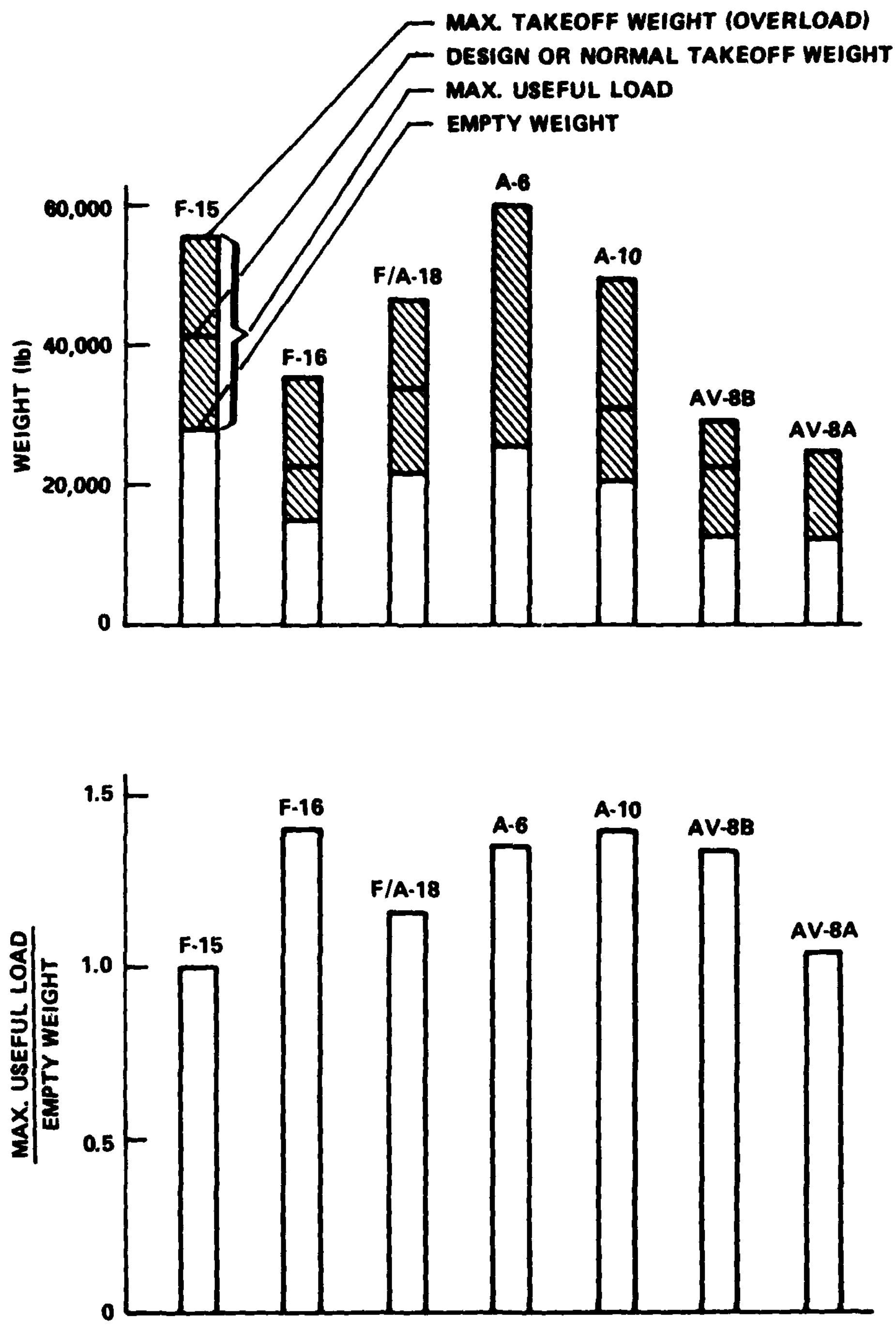


Figure 1 - Comparison of Useful Load Capability of Several Fighter and Attack Aircraft

(Reference -- Jane's All the Worlds Aircraft, 1979-80)

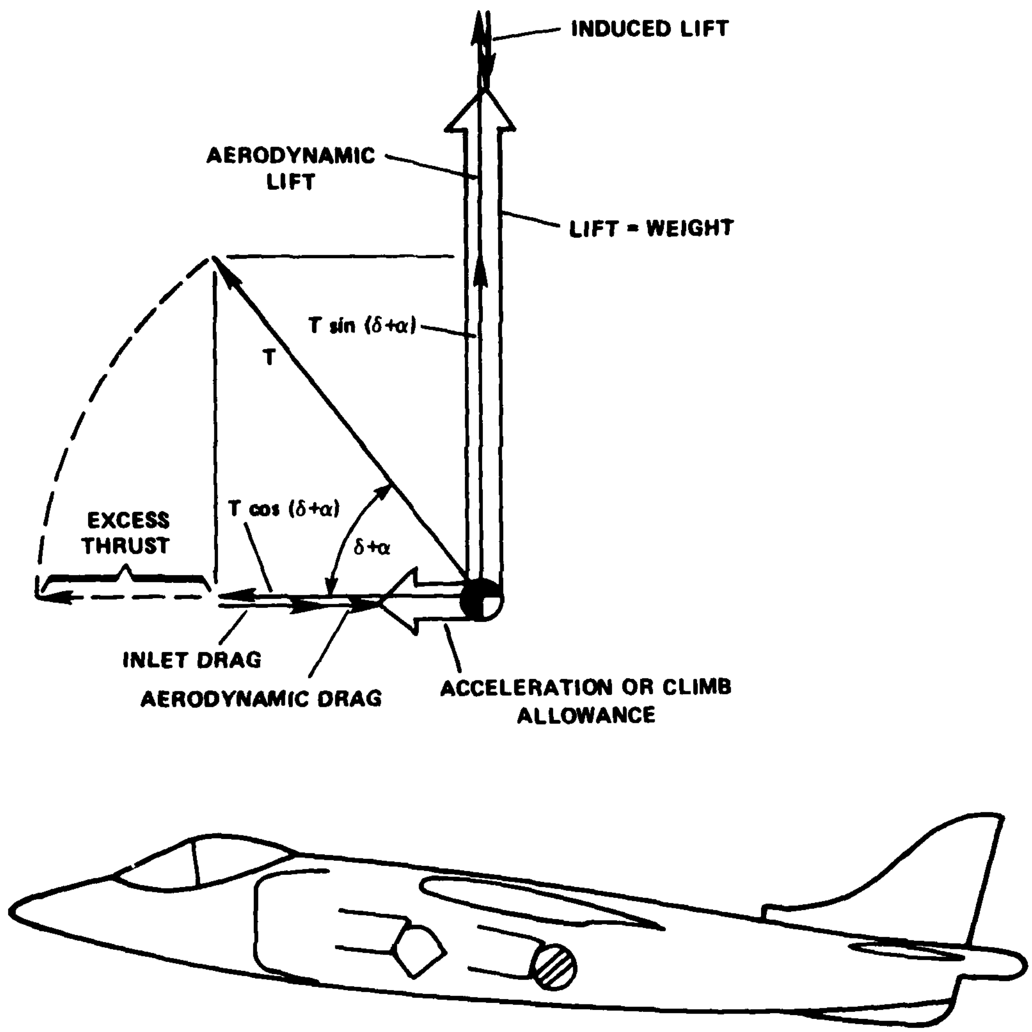


Figure 2 - Vector Presentation of the Lift-Weight and Thrust-Drag Components at Takeoff Speed

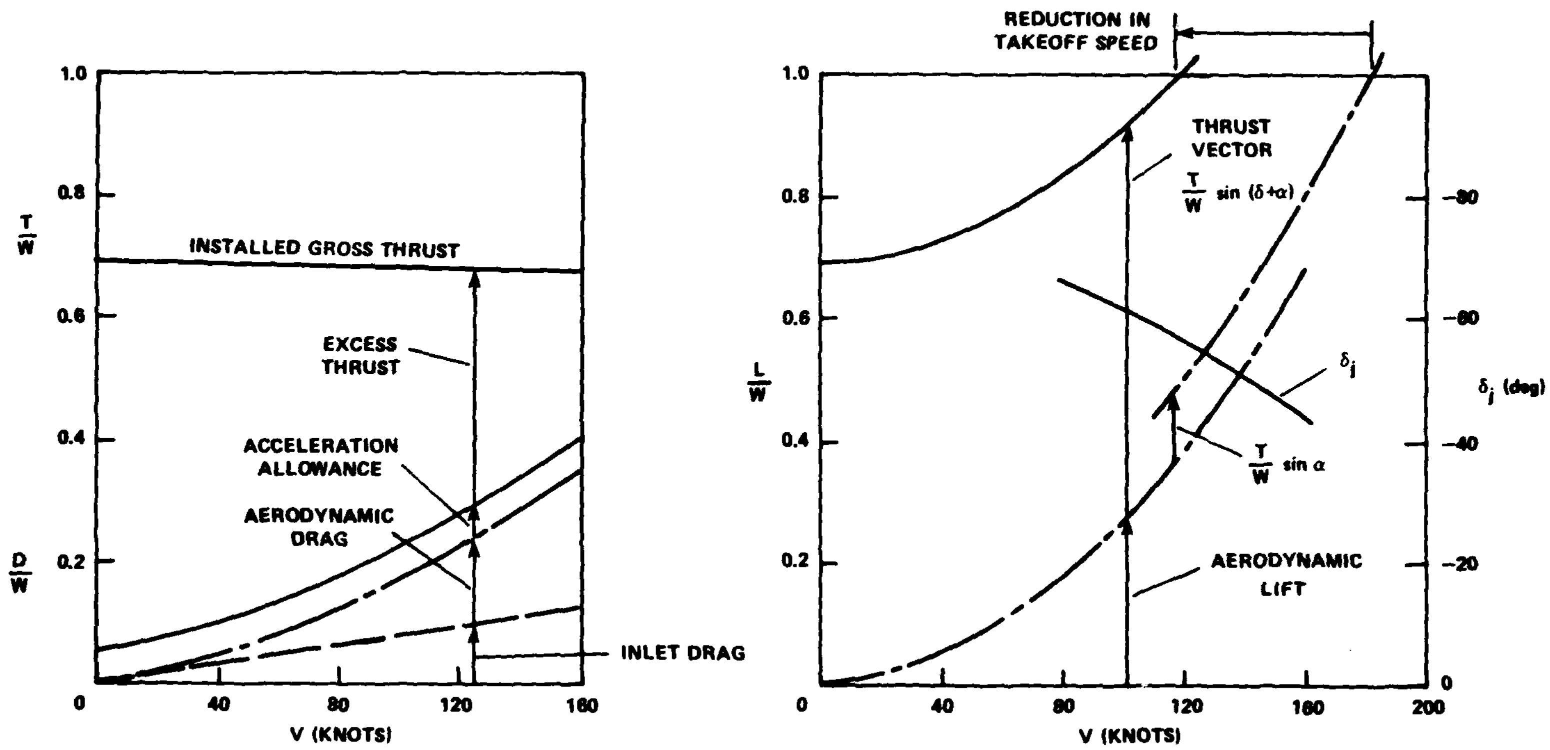


Figure 3 - Variation of Thrust, Drag, and Lift with Takeoff Speed; AV-8B, W = 29,550 Pounds

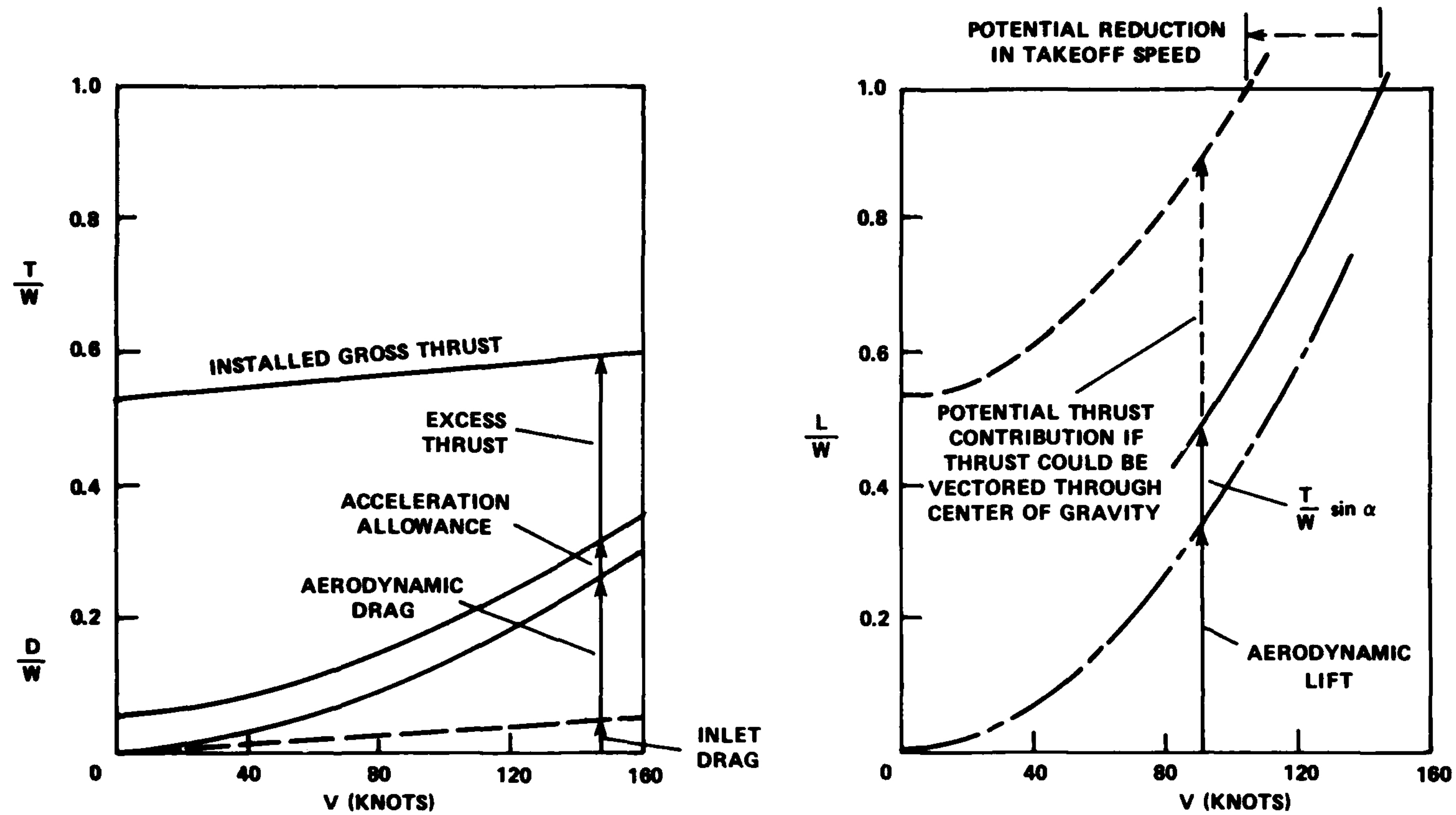


Figure 4 - Variation of Thrust, Drag, and Lift with Takeoff Speed;
F/A-18, W = 47,000 Pounds

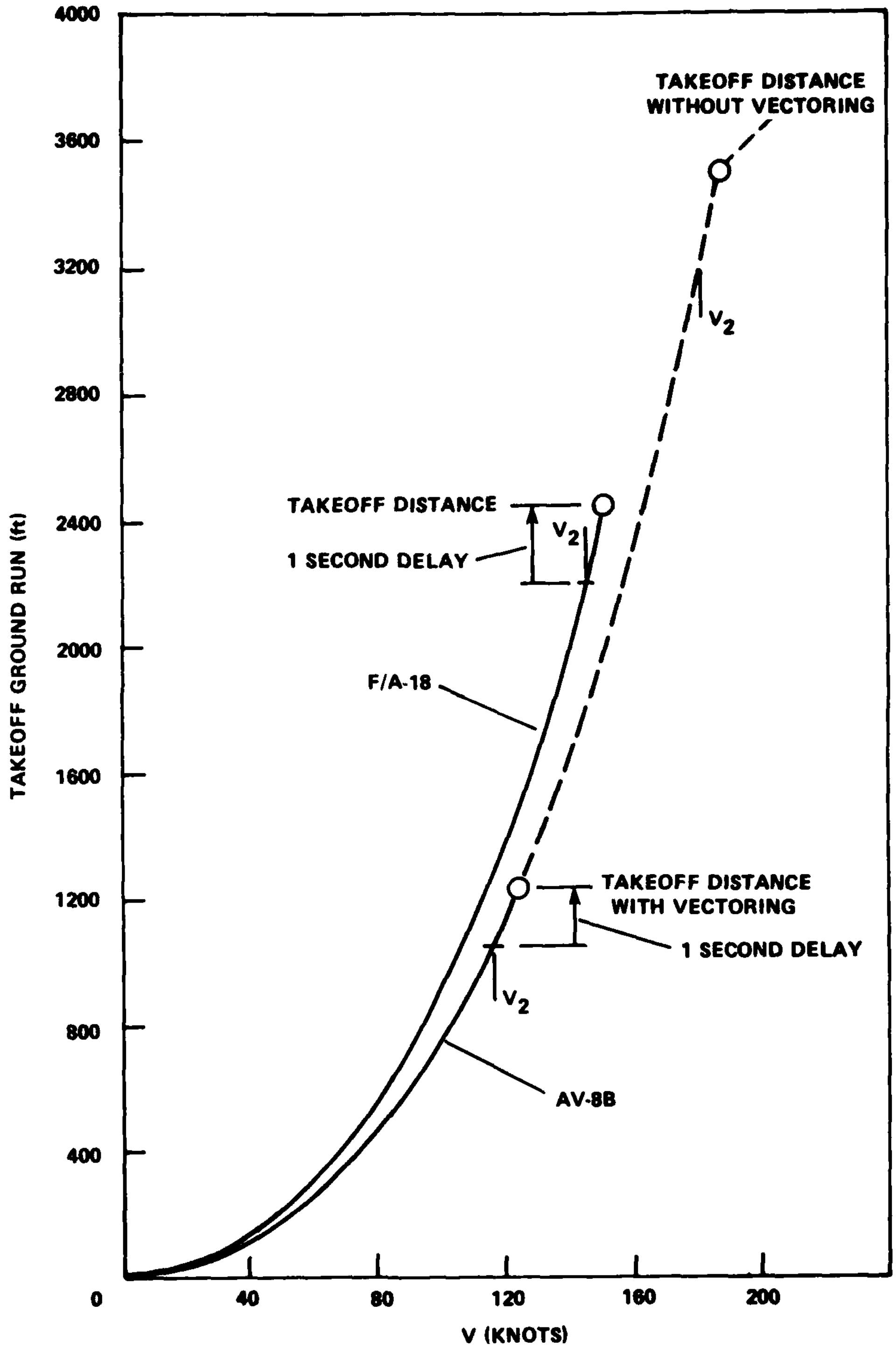


Figure 5 - Takeoff Distance

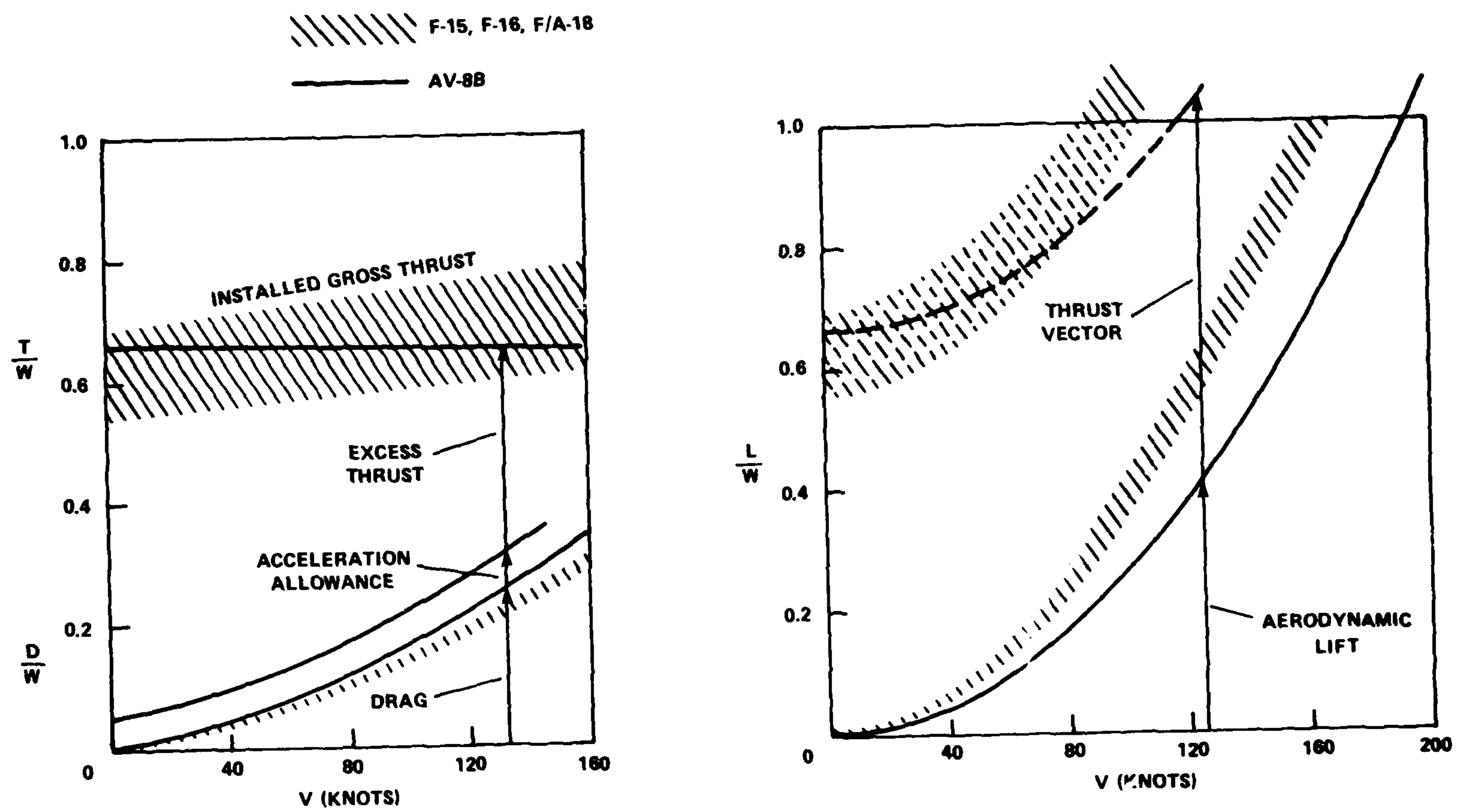


Figure 6 - Comparison of High Performance Fighter-Attack Aircraft

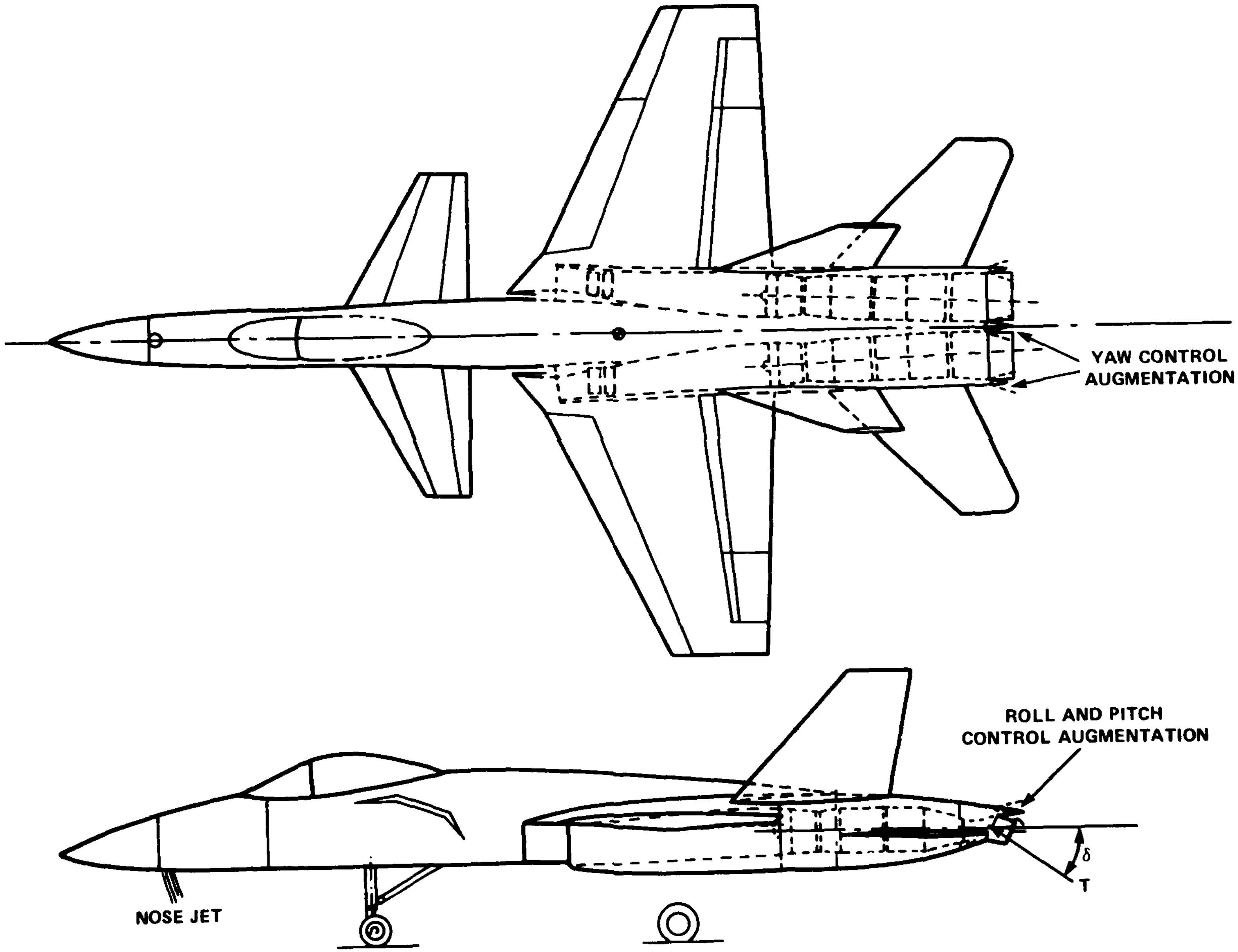


Figure 7 - Assumed Modifications to CTOL Configuration

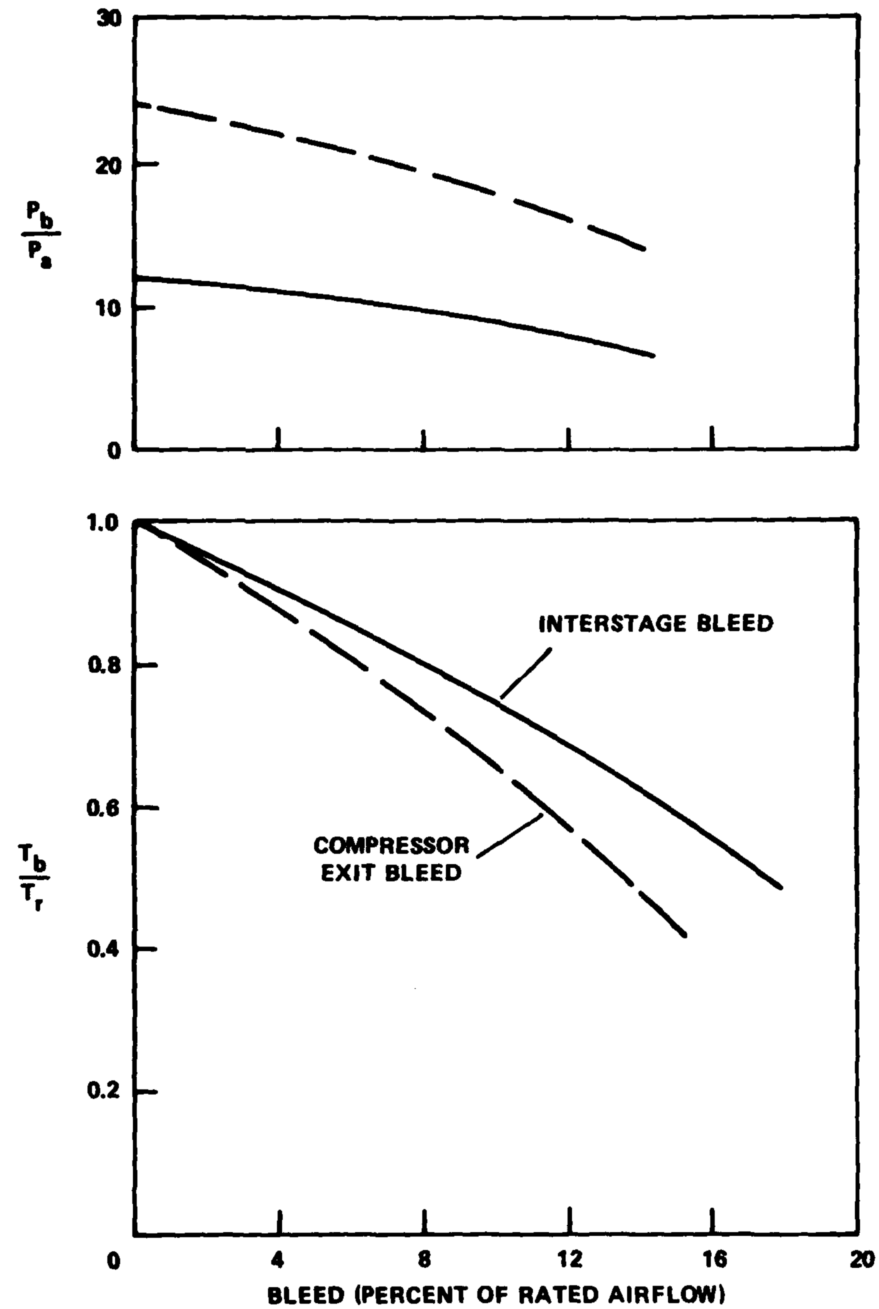


Figure 8 - Assumed Effect of Bleed on Engine Thrust

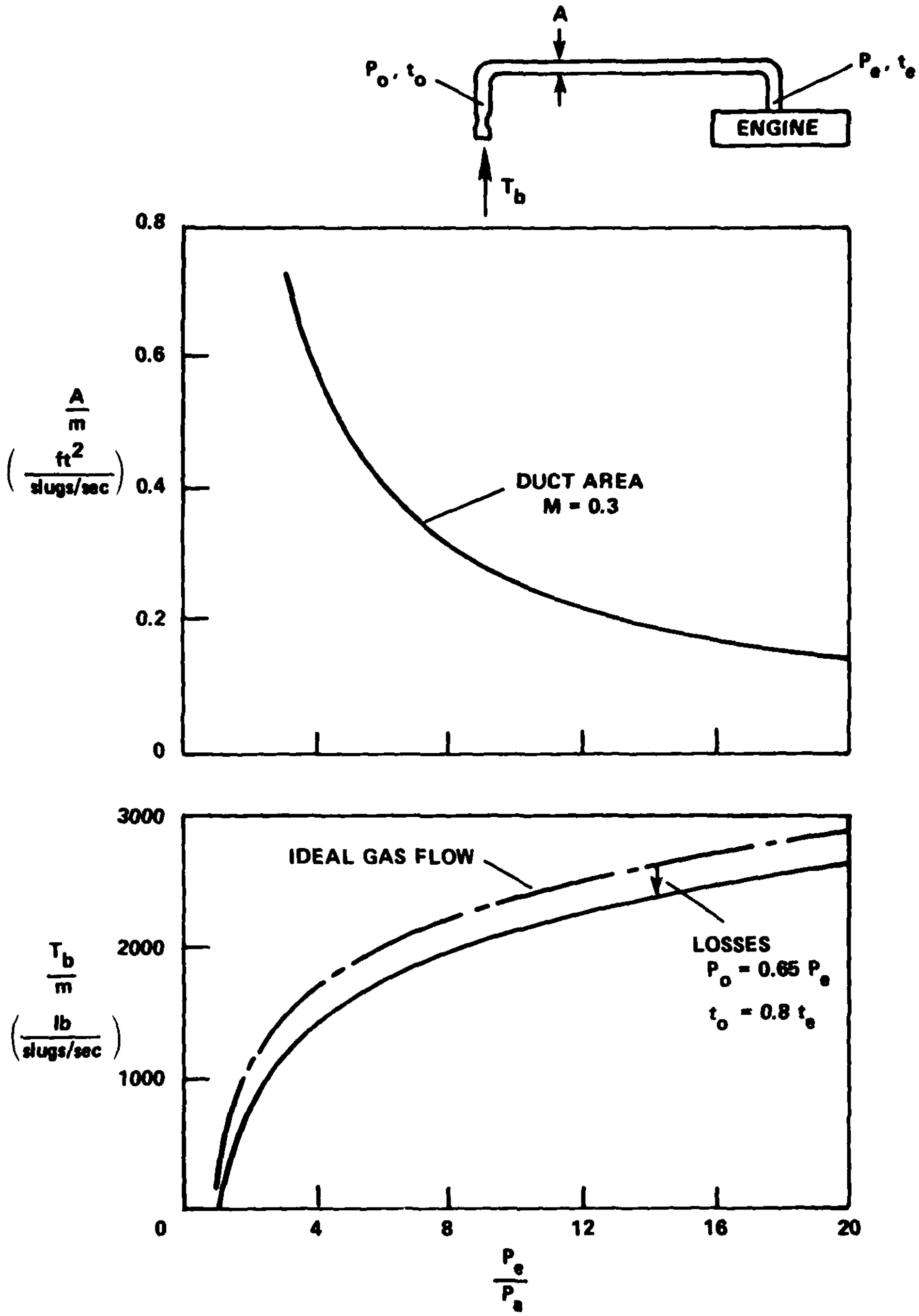


Figure 9 - Thrust Available from Bleed Air and Duct Area Required

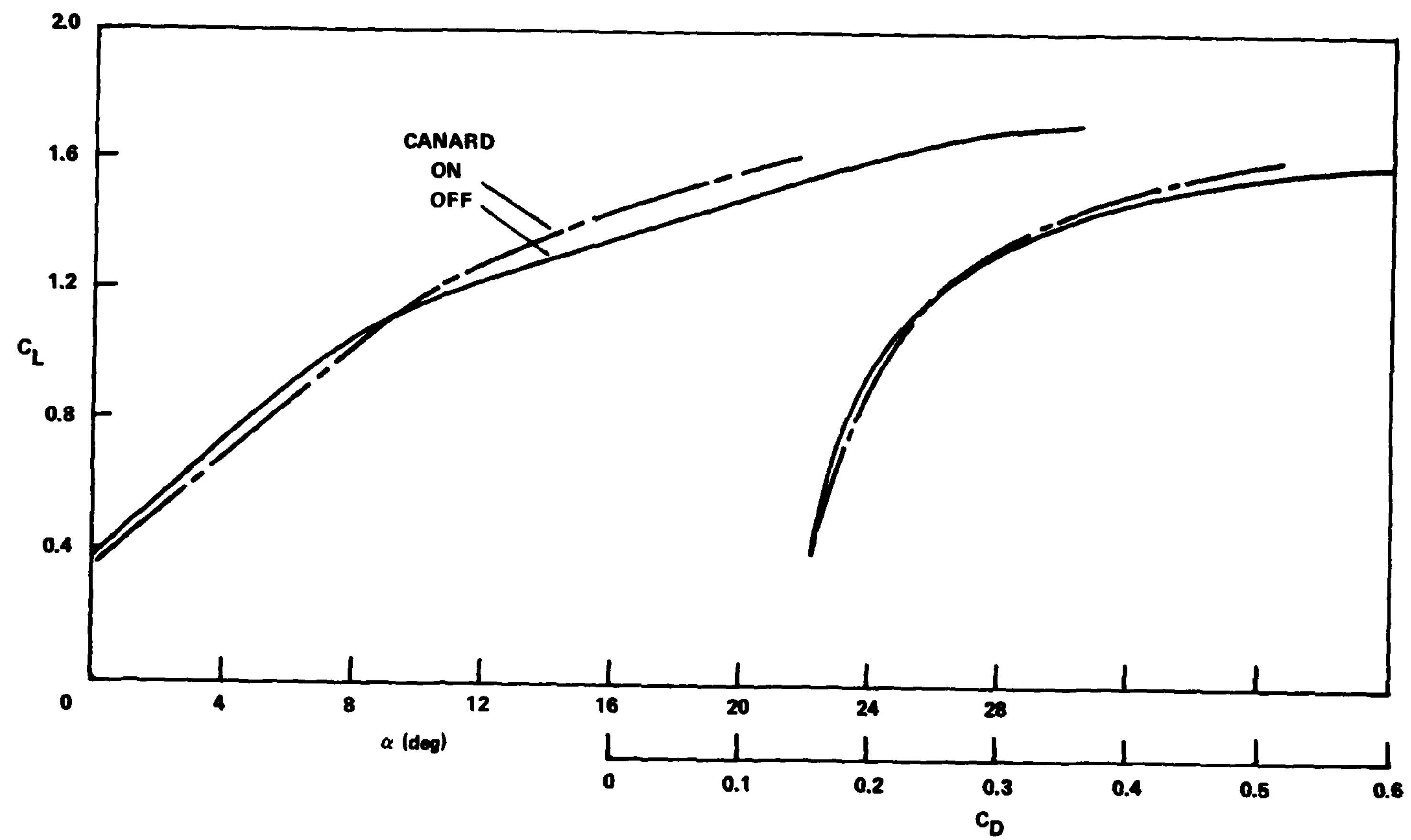


Figure 10 - Assumed Aerodynamic Characteristics, Takeoff Configuration

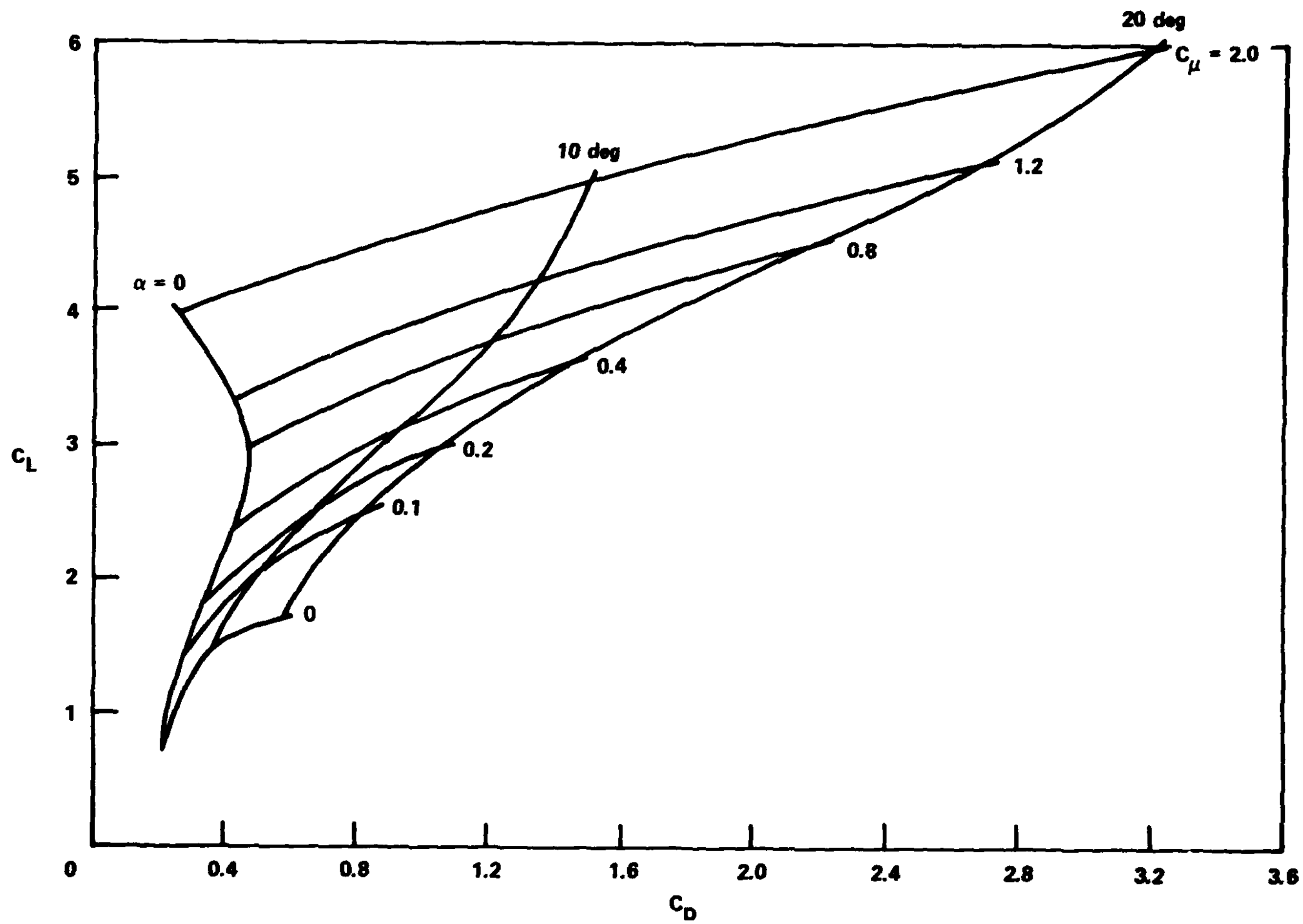


Figure 11 - Estimated Aerodynamic Characteristics of Jet Flap Configuration; δ = 60 Degrees, Aspect Ratio 3.5 (Reference 2)

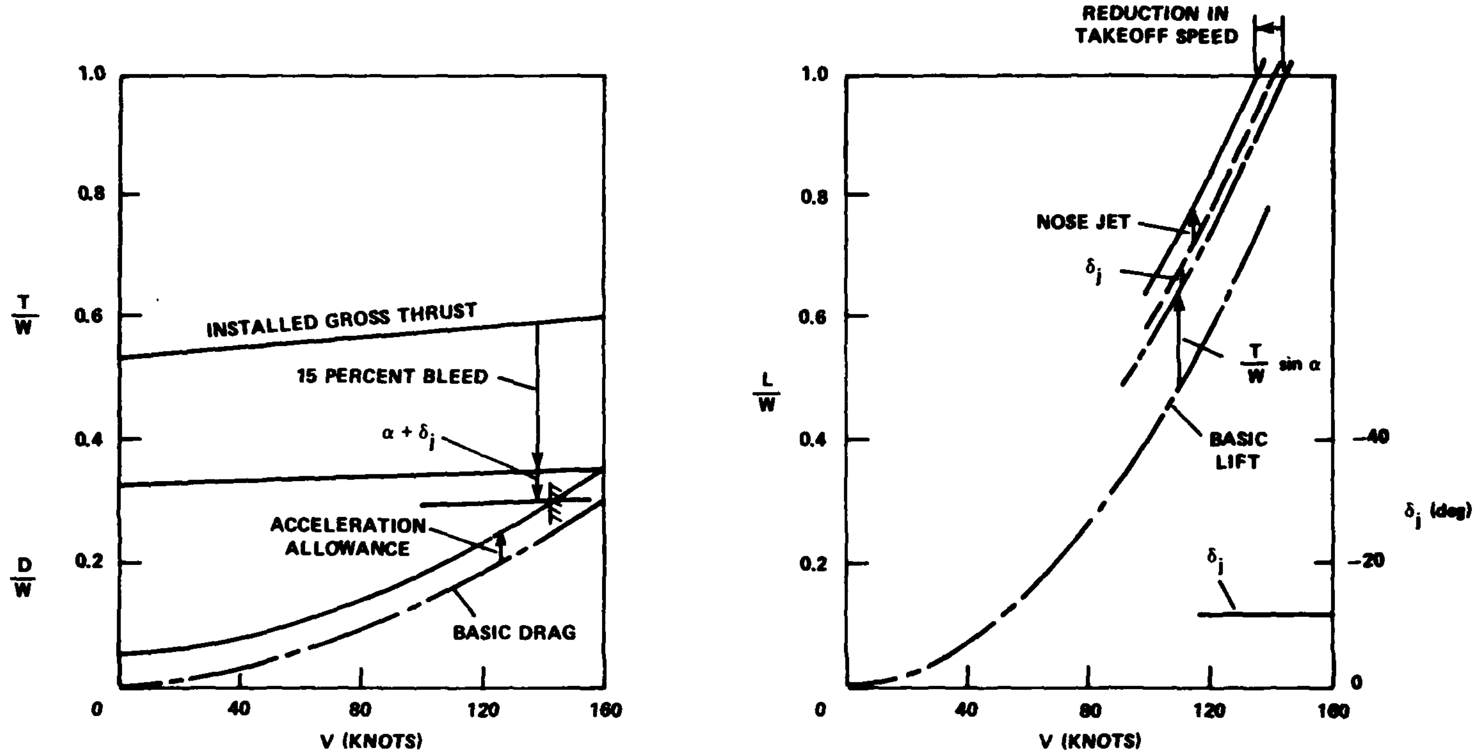


Figure 12 - Effect of Nose Jet; 15 Percent Bleed, Canard Off

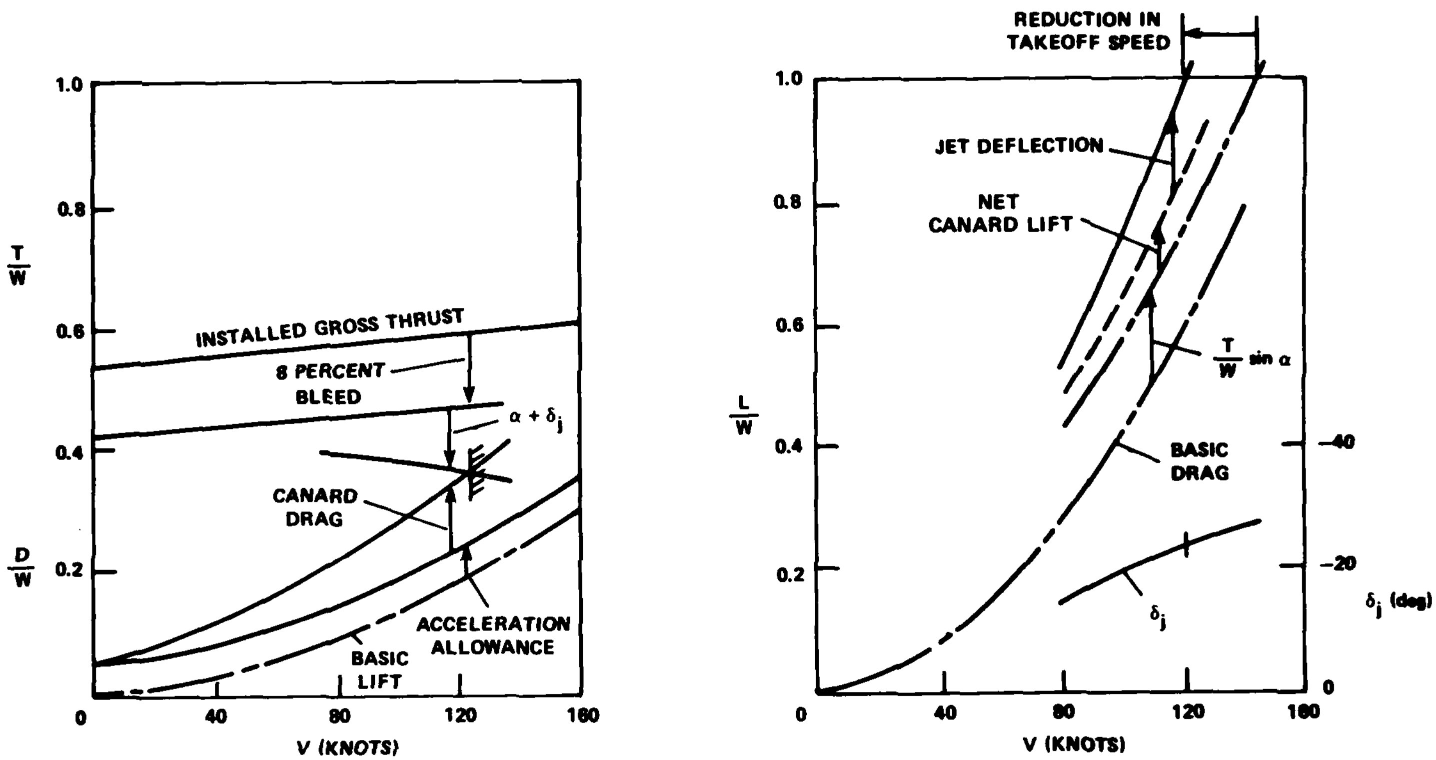
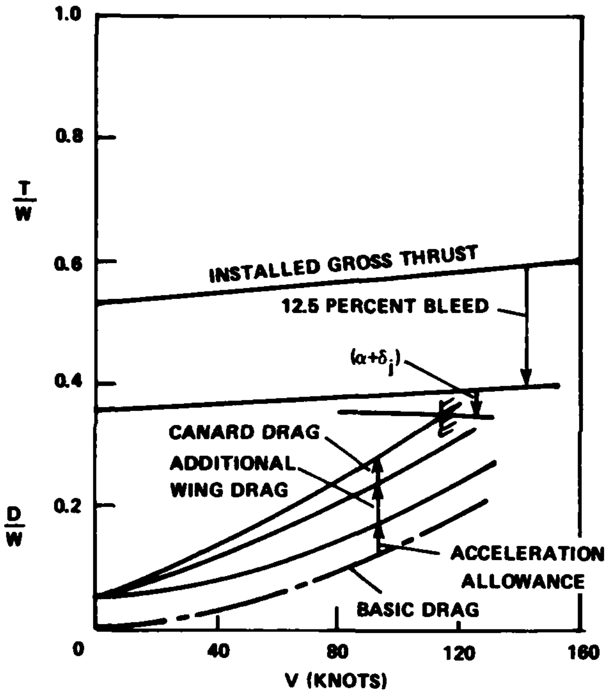


Figure 13 - Effect of Jet Flap Canard; 8 Percent Bleed



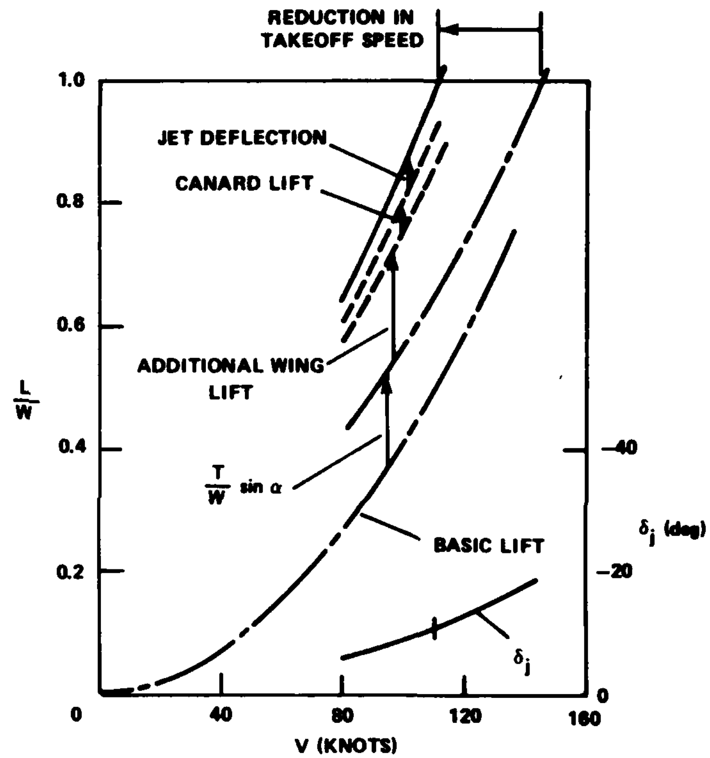


Figure 14 - Effect of Jet Flap on Wing and Canard; 10 Percent Bleed to Wing, 2.5 Percent Bleed to Canard

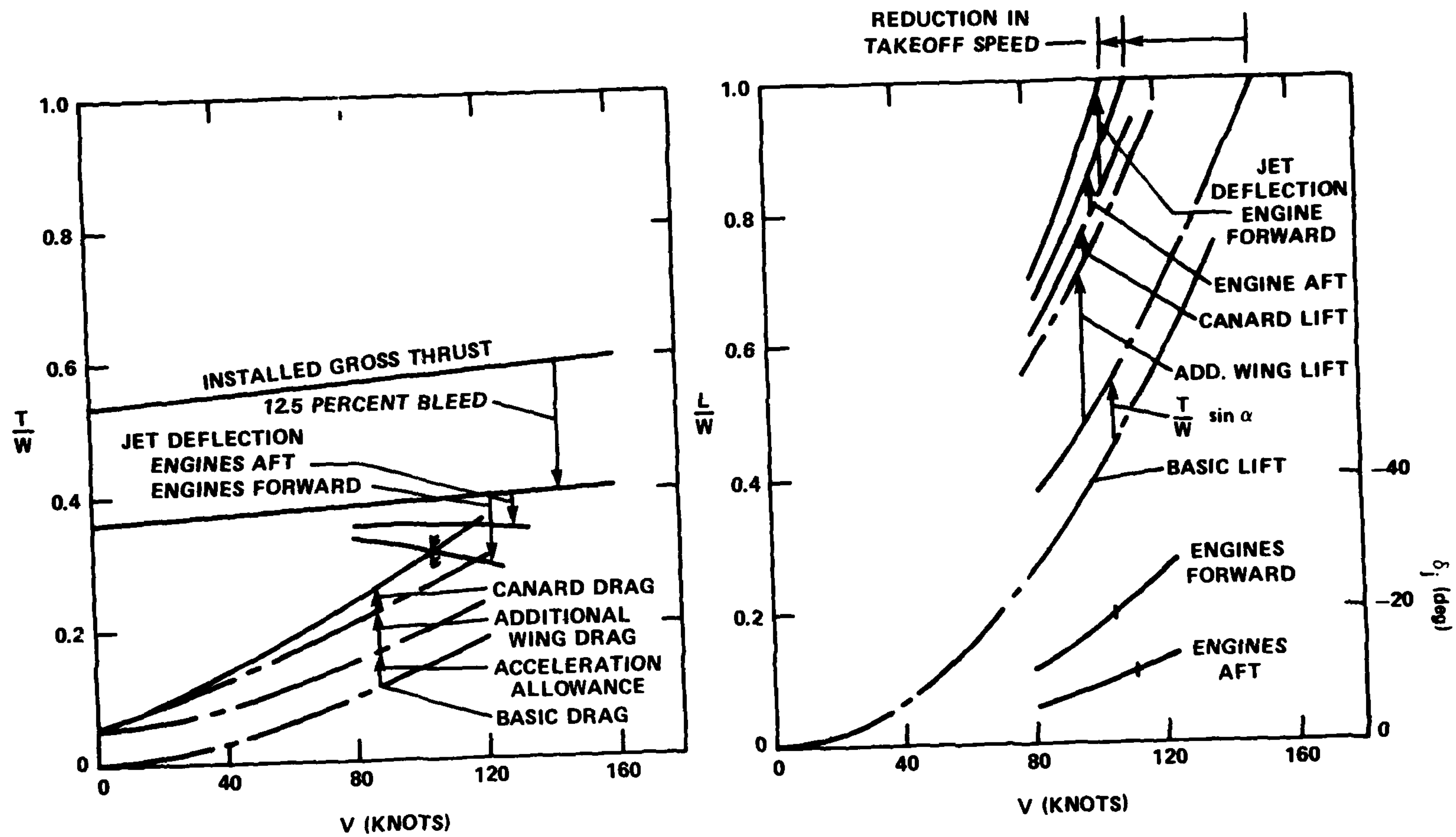


Figure 15 - Effect of Engine Position; 10 Percent Bleed to Wing, 2.5 Percent Bleed to Canard

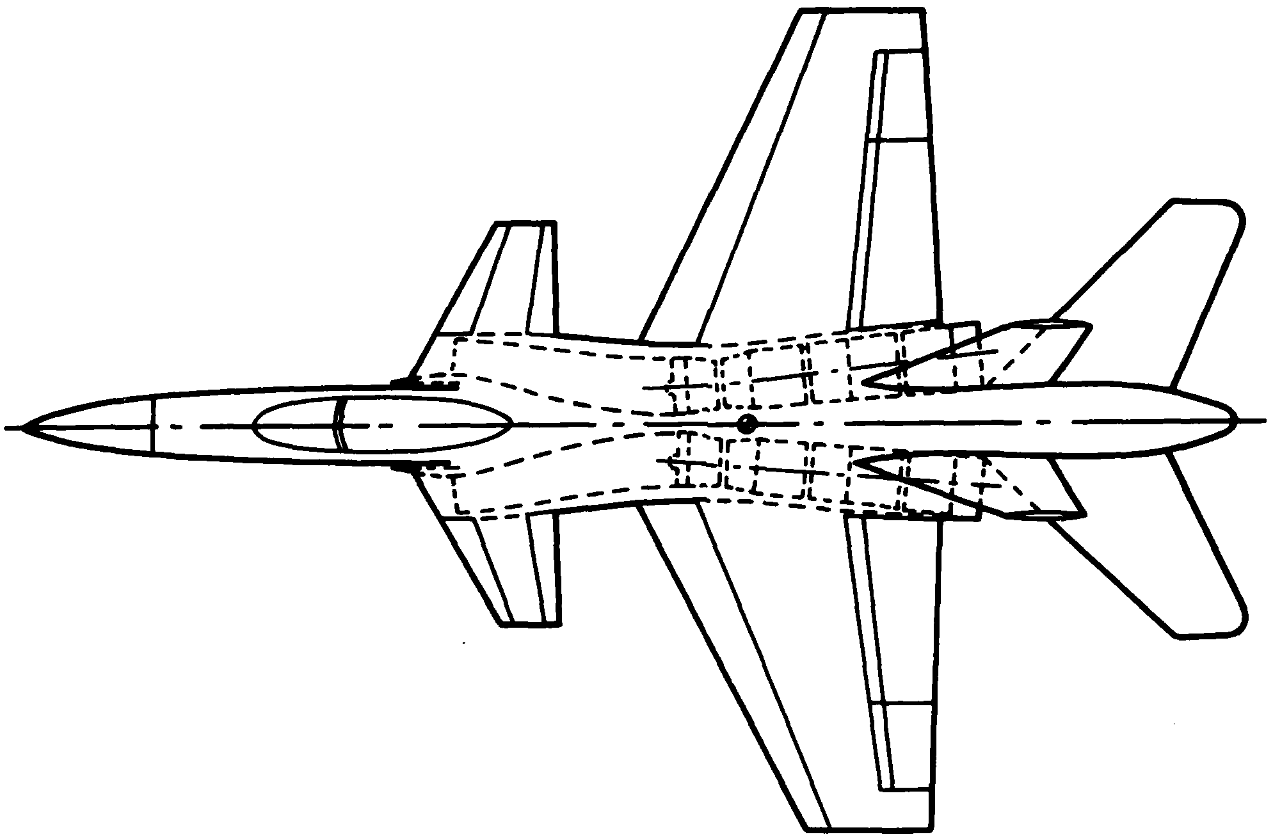


Figure 16 - Configuration with Engines Moved Forward; 10 Percent Bleed to Wing, 2.5 Percent Bleed to Canard

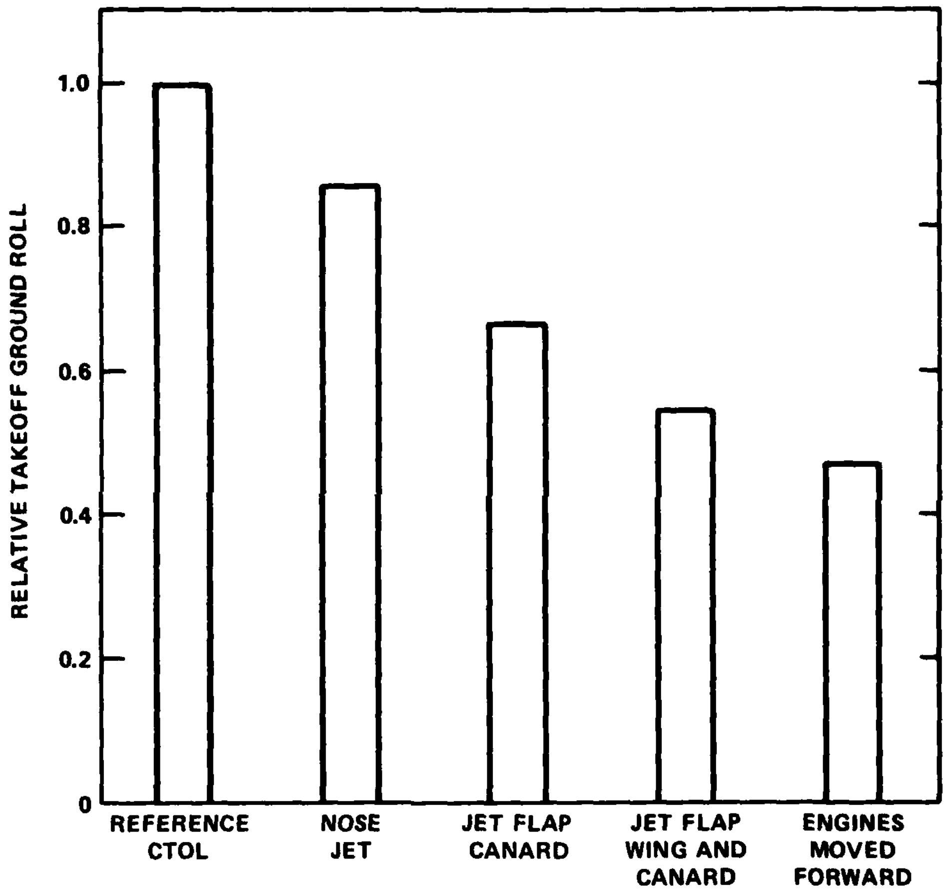


Figure 17 - Comparison of Takeoff Performance

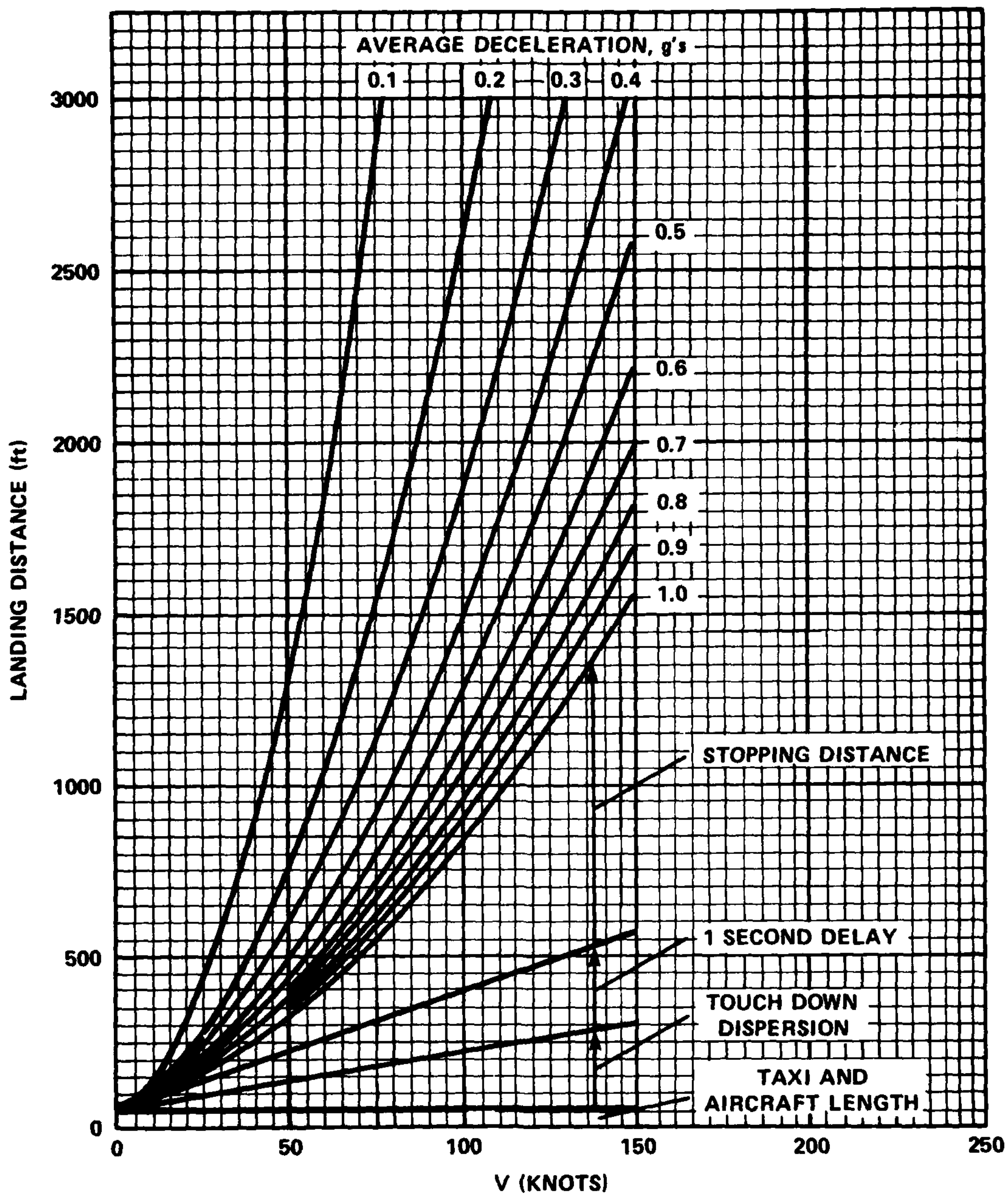


Figure 18 - Landing Distance

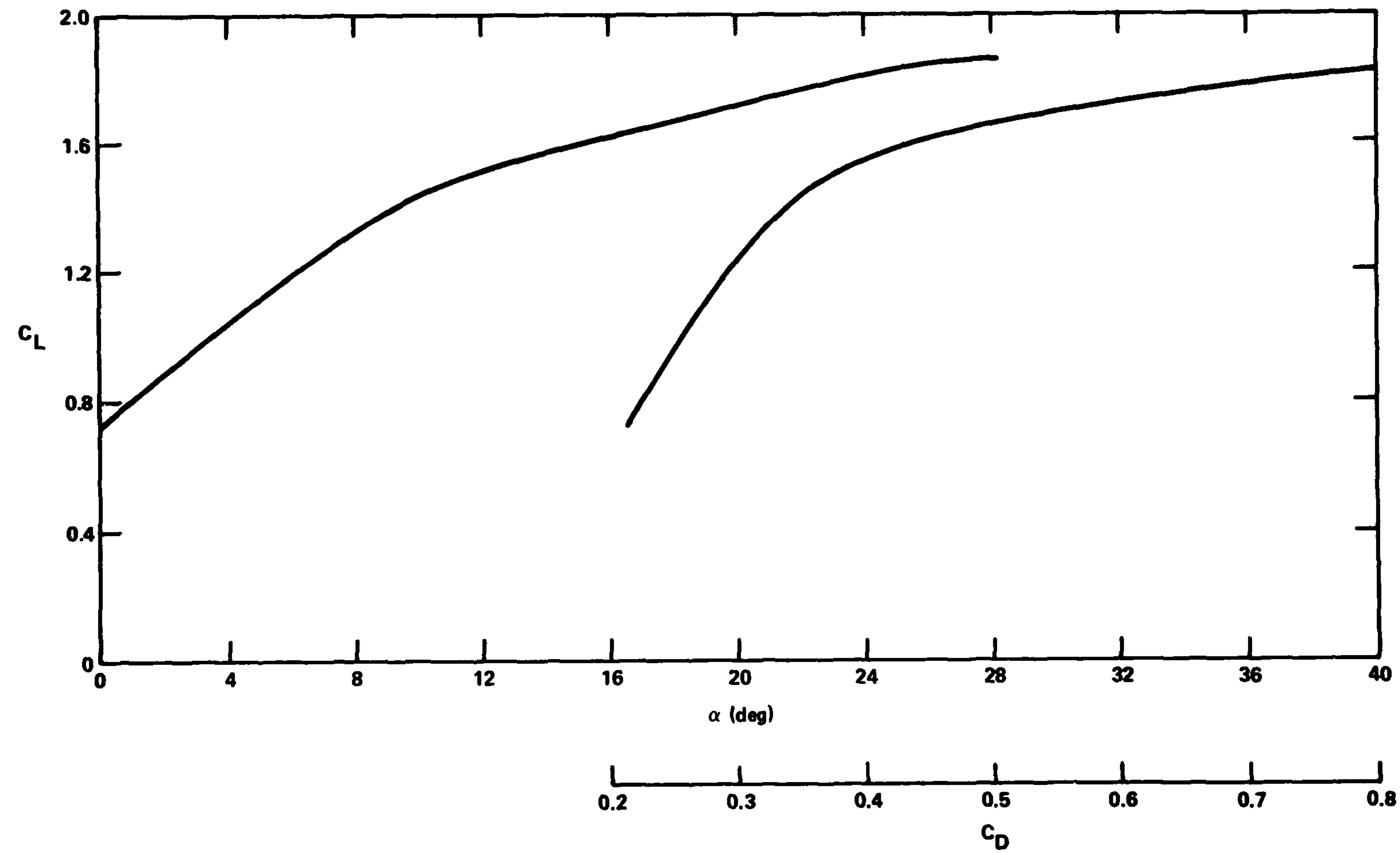


Figure 19 - Assumed Aerodynamic Characteristics, Landing Configuration

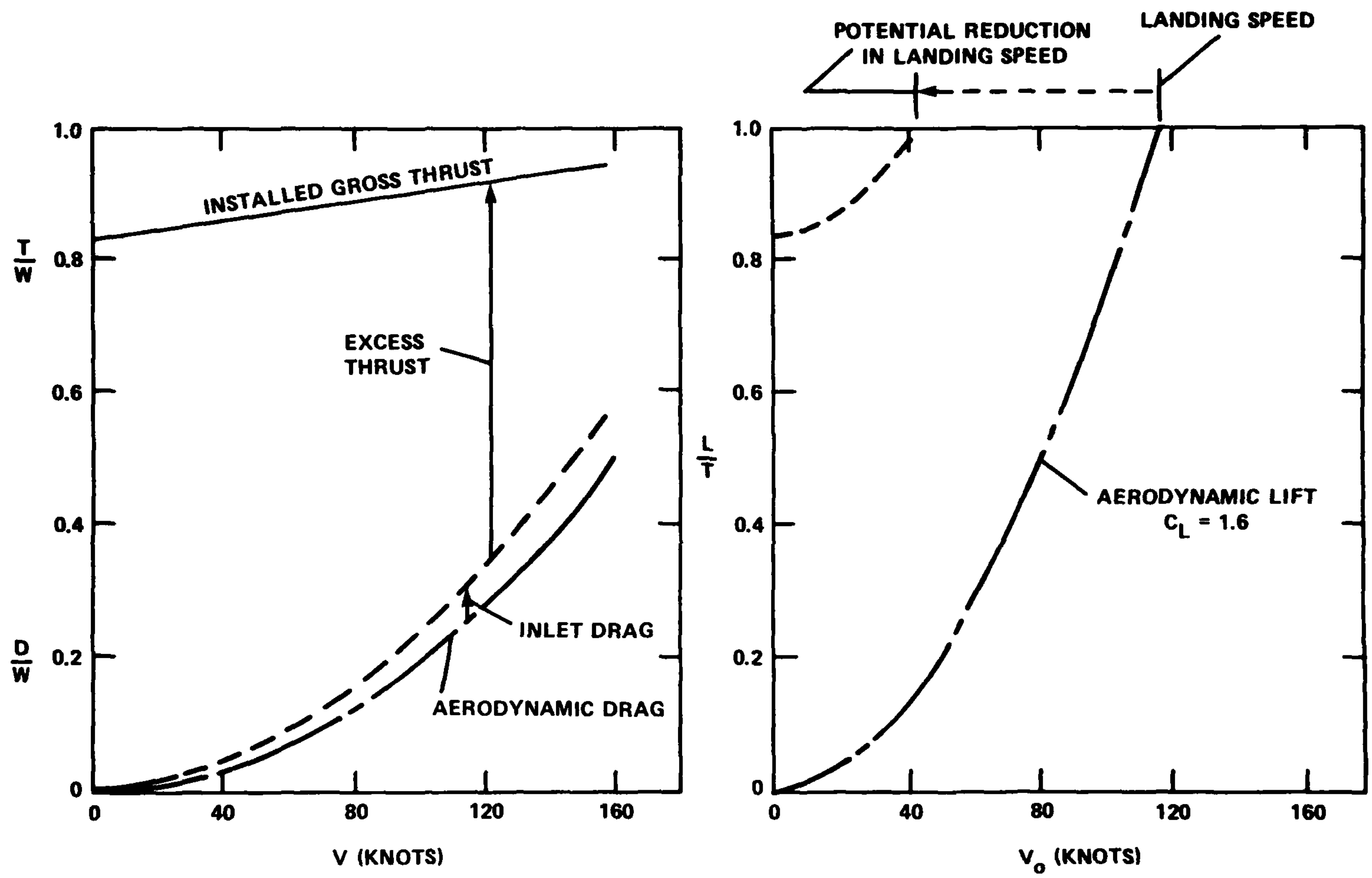


Figure 20 - Power Off Landing Performance;
S = 400 Square Feet; W = 30,000 Pounds

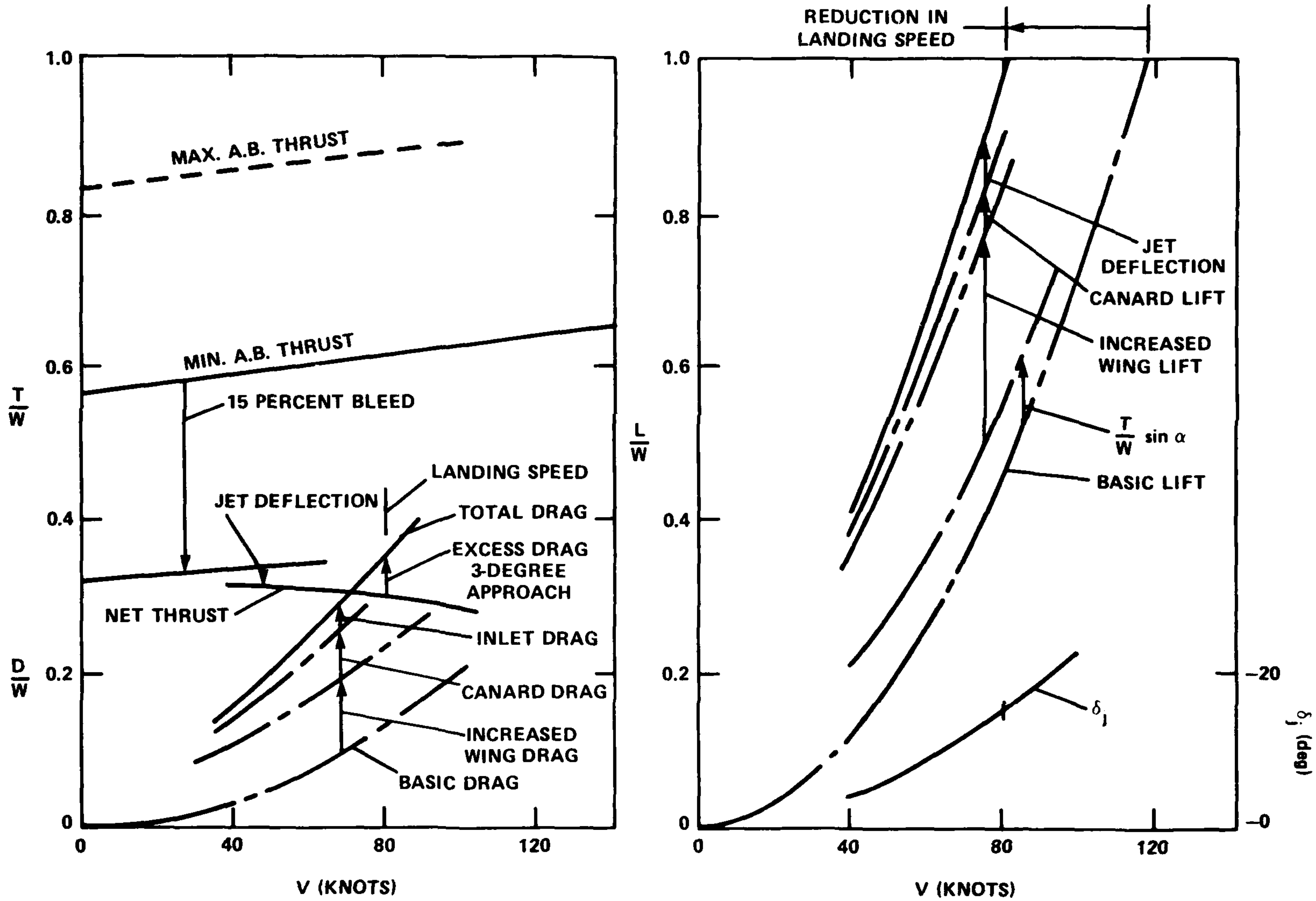


Figure 21 - Landing Performance of Jet Flap Configuration; 10 Percent Bleed to Wing, 5 Percent Bleed to Canard, S = 400 Square Feet, W = 30,000 Pounds

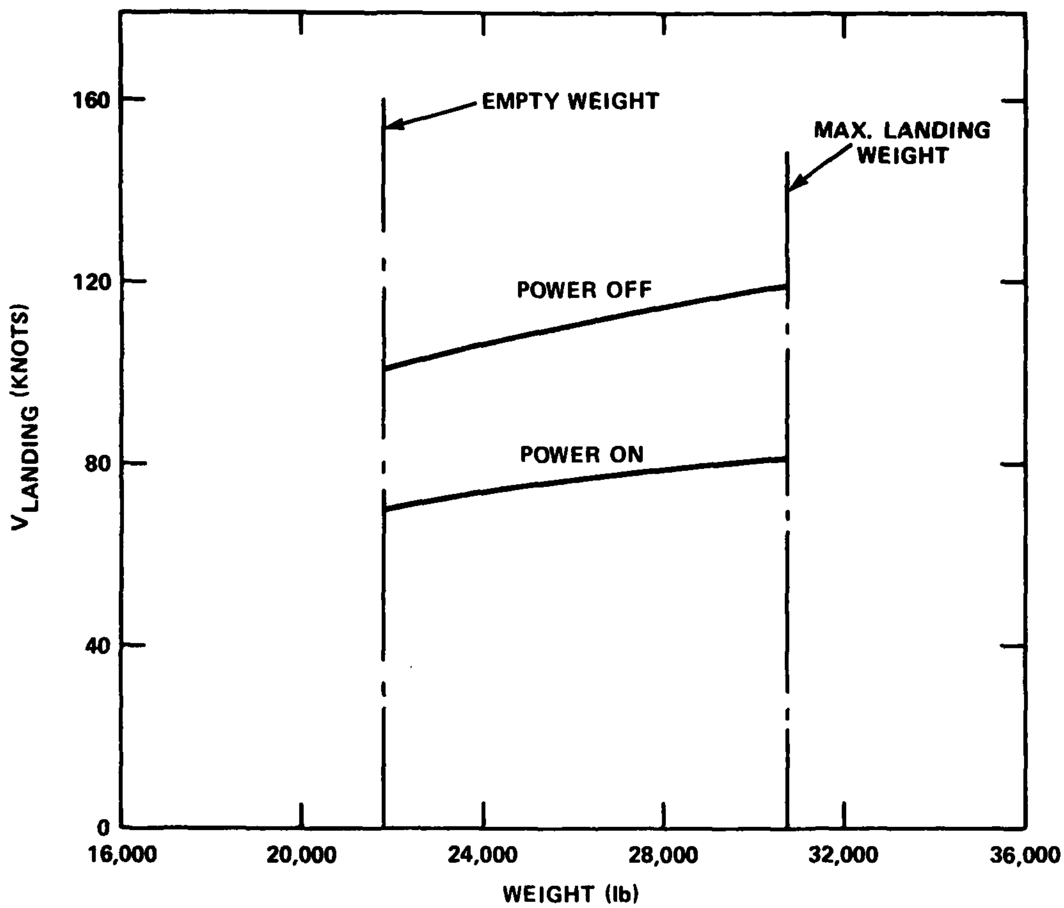


Figure 22 - Variation of Landing Speed with Landing Weight, S = 400 Square Feet

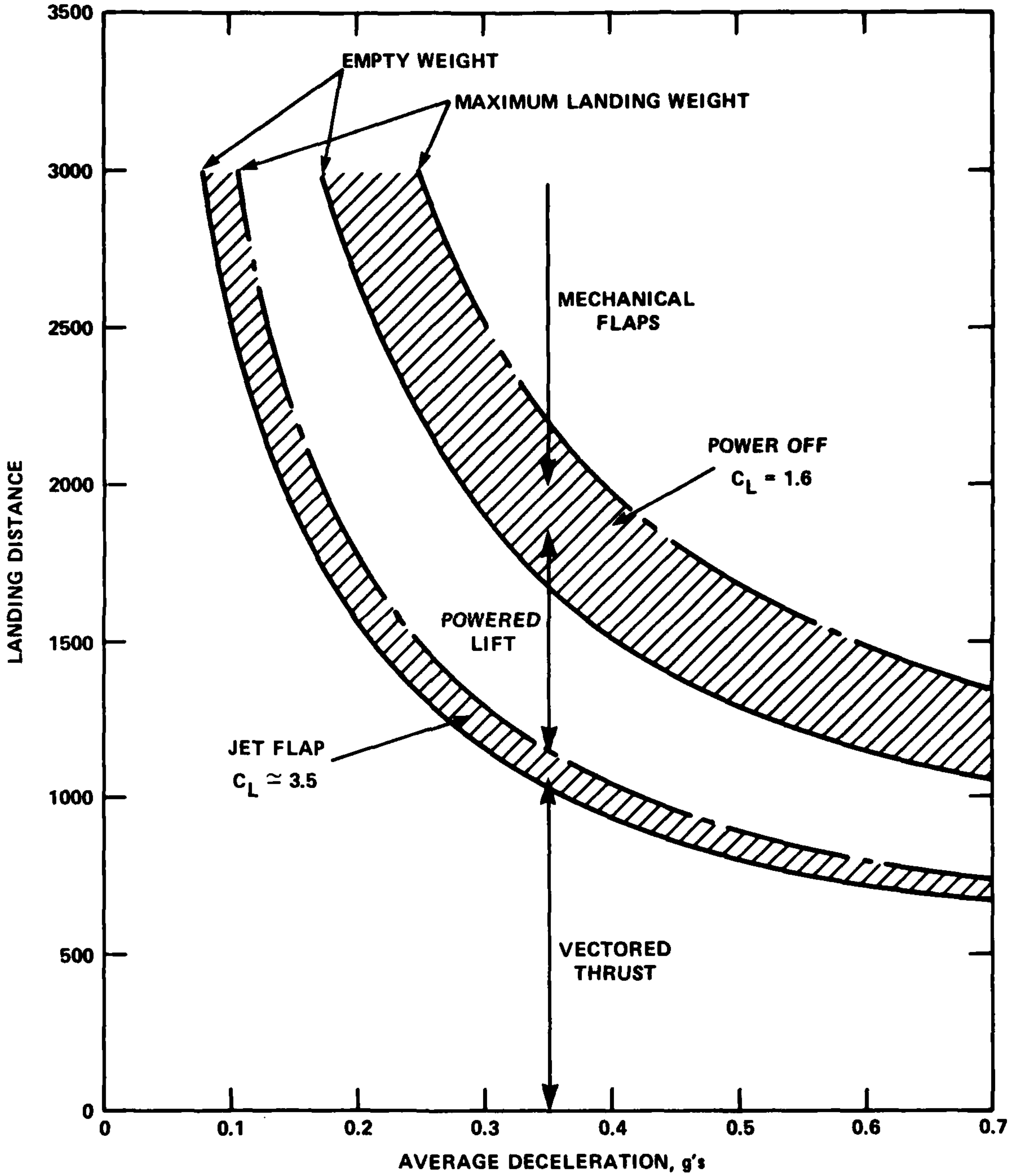


Figure 23 - Effect of Lifting System and Deceleration Capability on Landing Distance

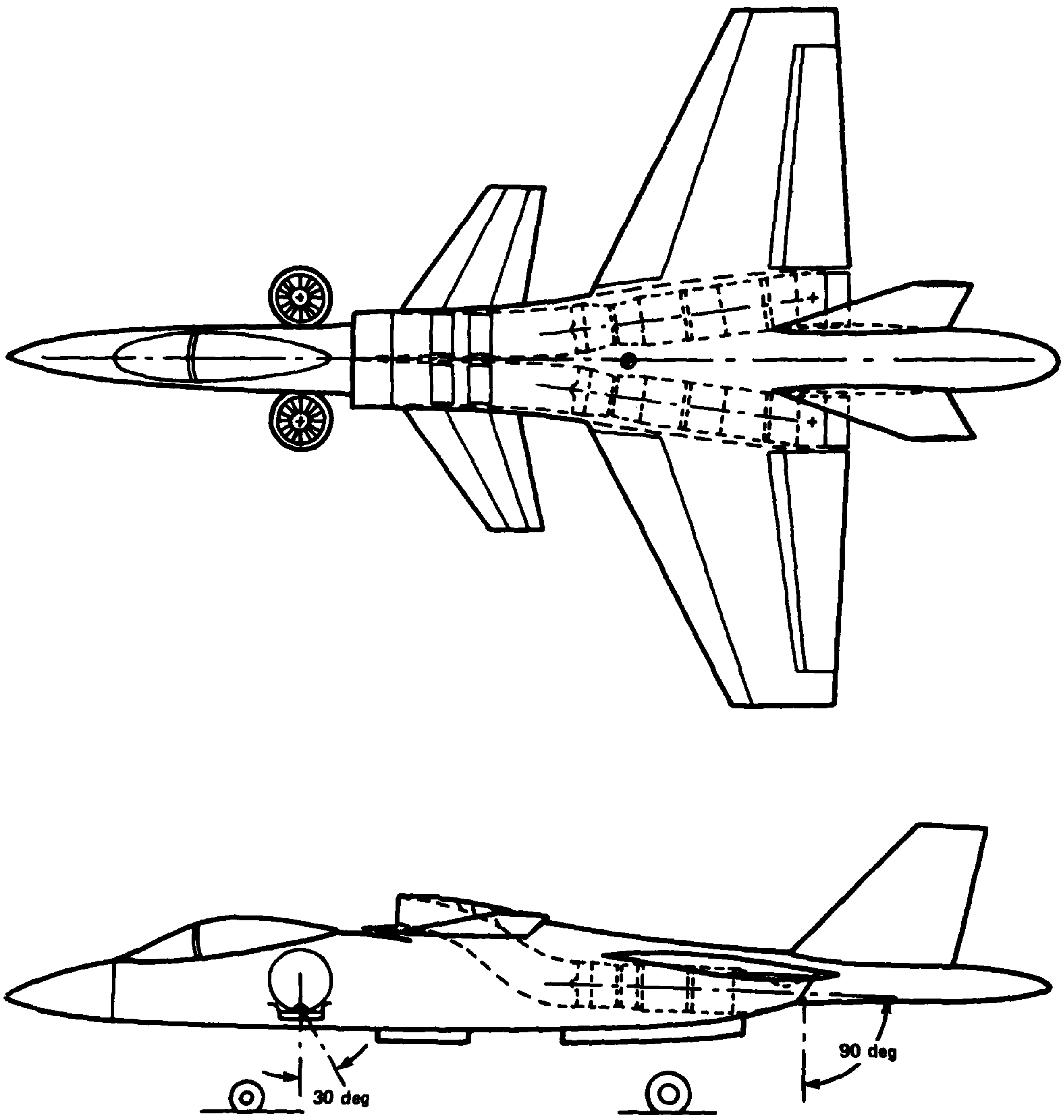


Figure 24 - Lift Fan STO-VL Configuration

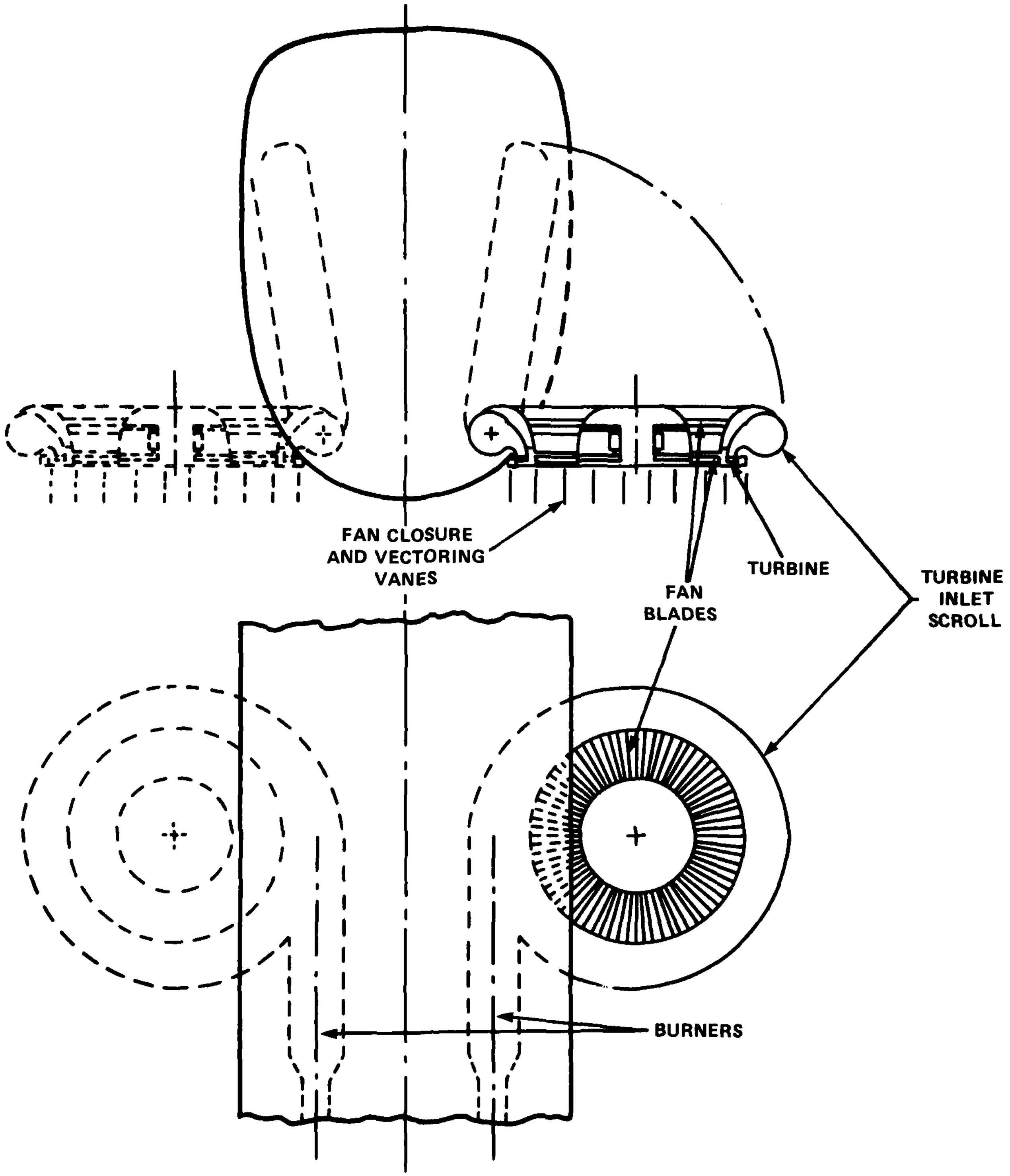


Figure 25 - Schematic of Fan Installation

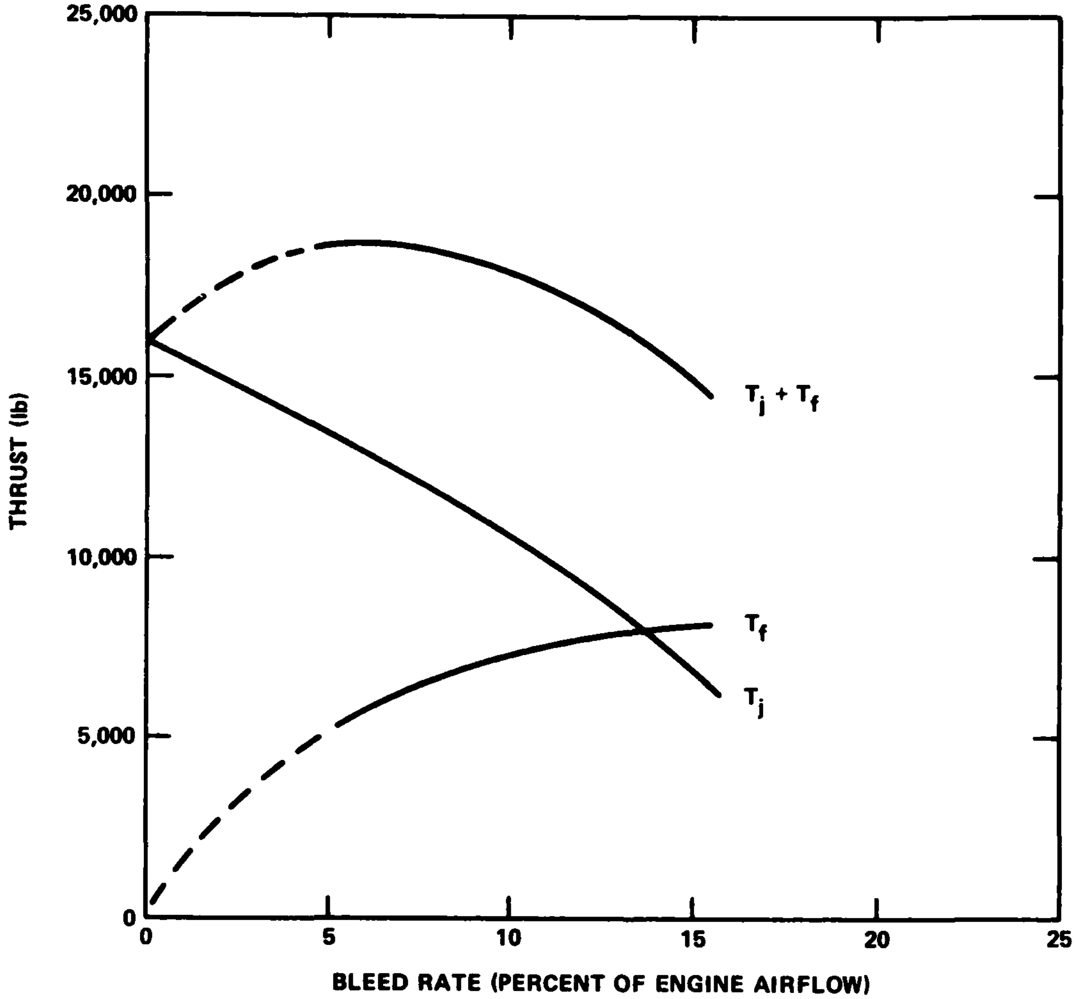
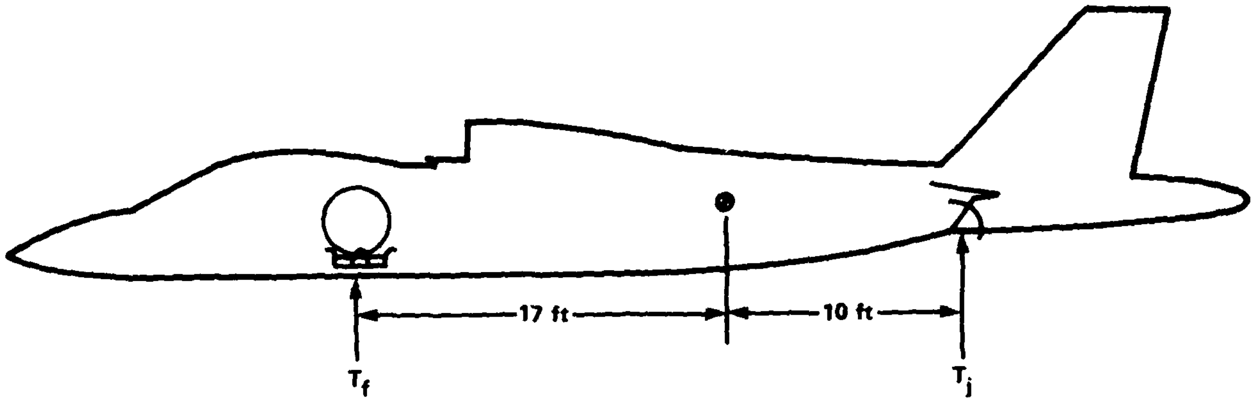


Figure 26 - Estimated Fan Performance Uninstalled



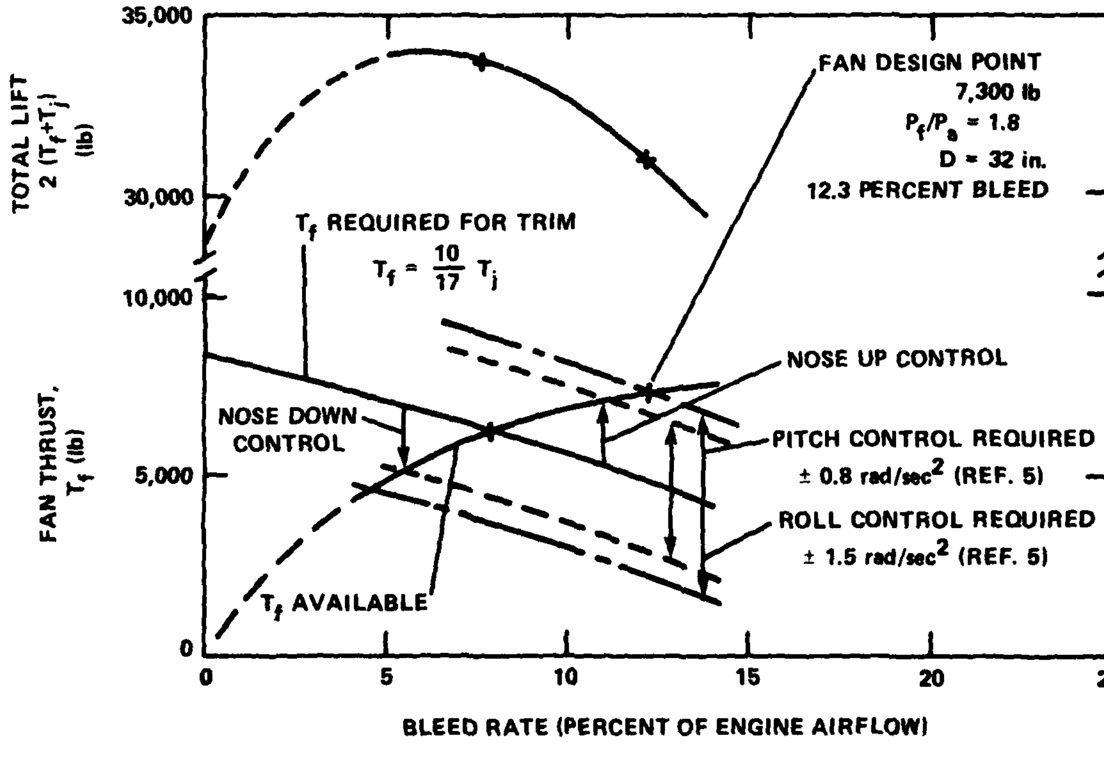


Figure 27 - Fan and Main Jet Thrust Required for Trim and Control

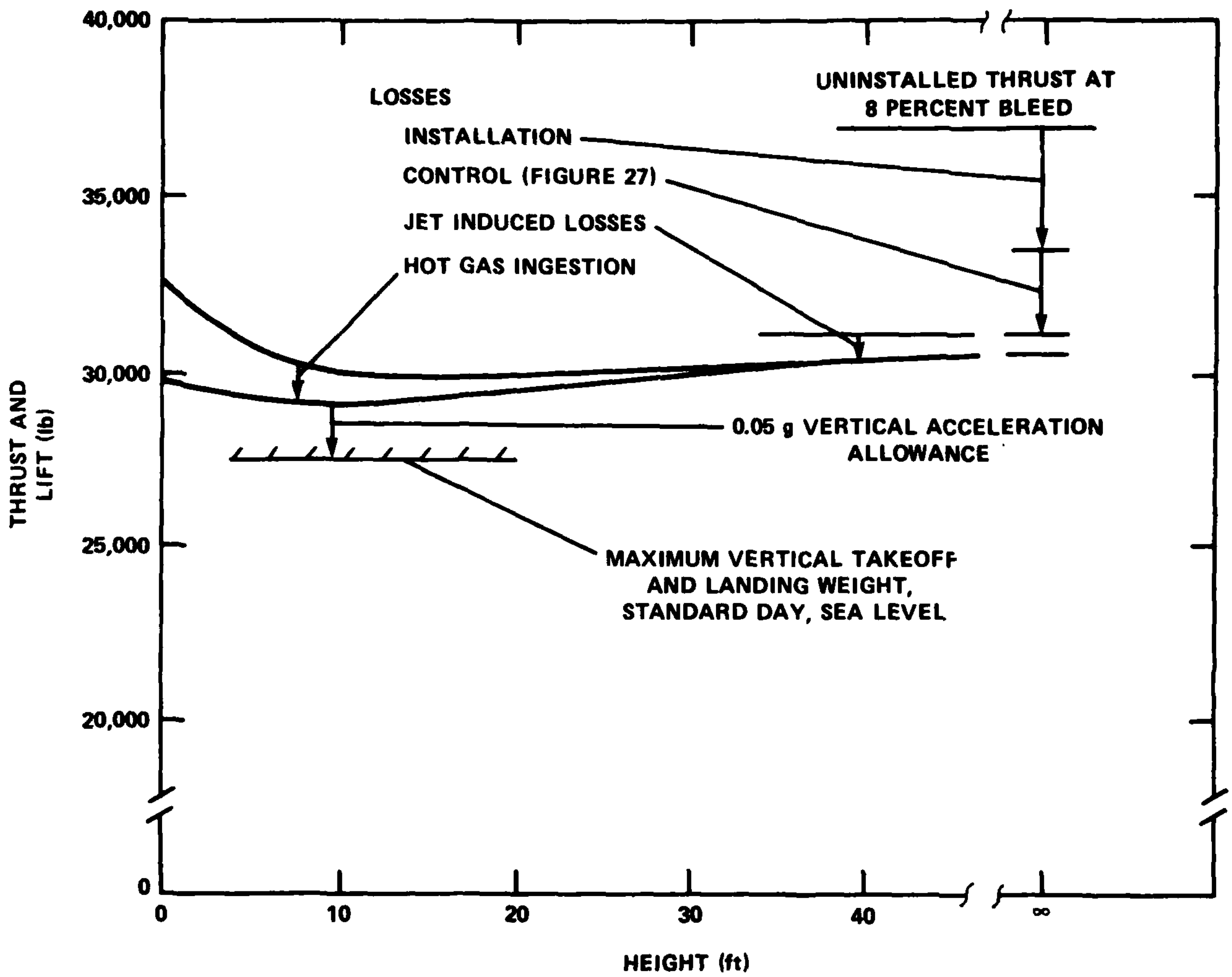


Figure 28 - Estimate of Maximum Vertical Takeoff and Landing Weight

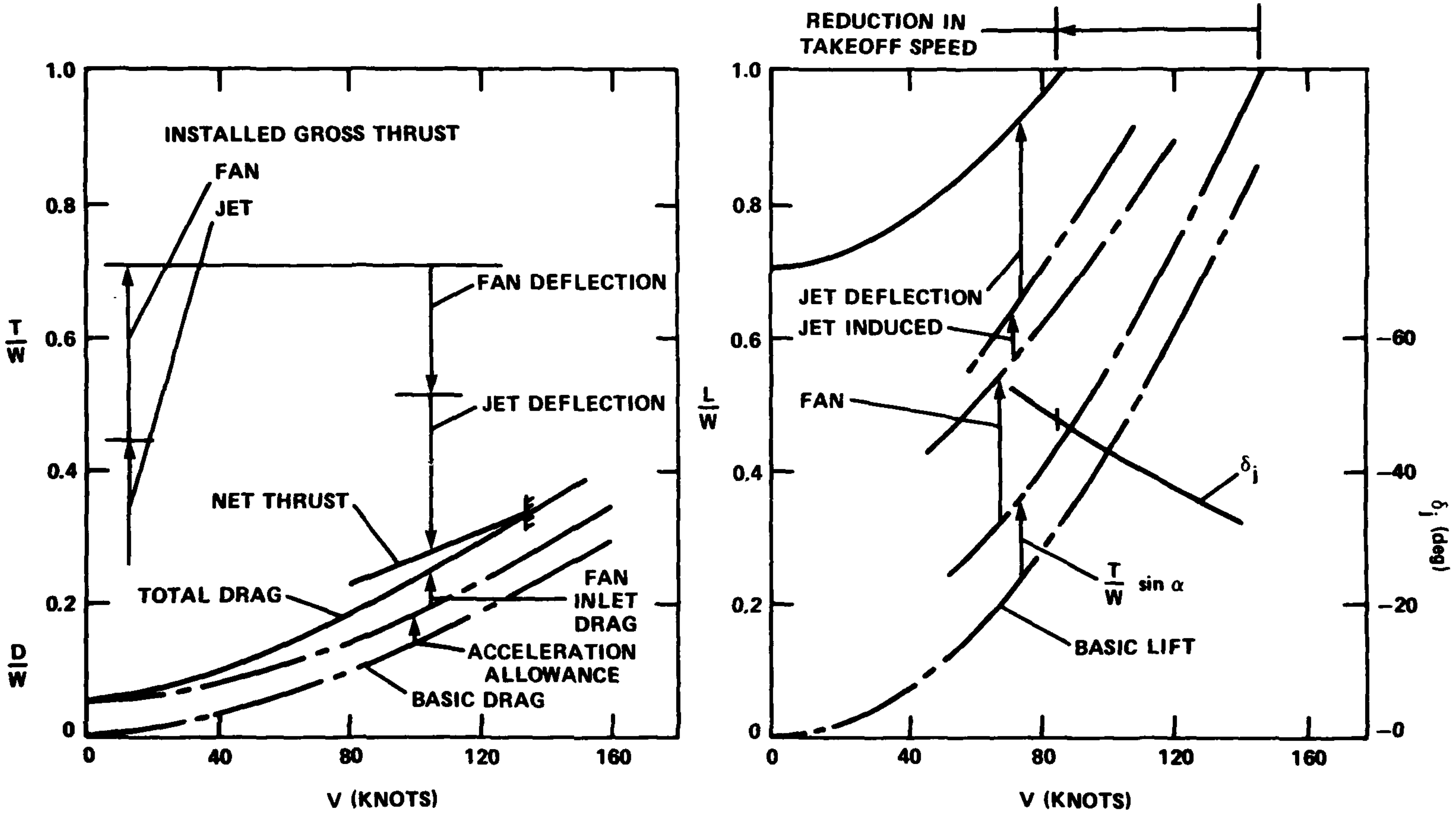


Figure 29 - Takeoff Performance of Lift Fan STO-VL Configuration
at 47,000 Pounds Takeoff Weight

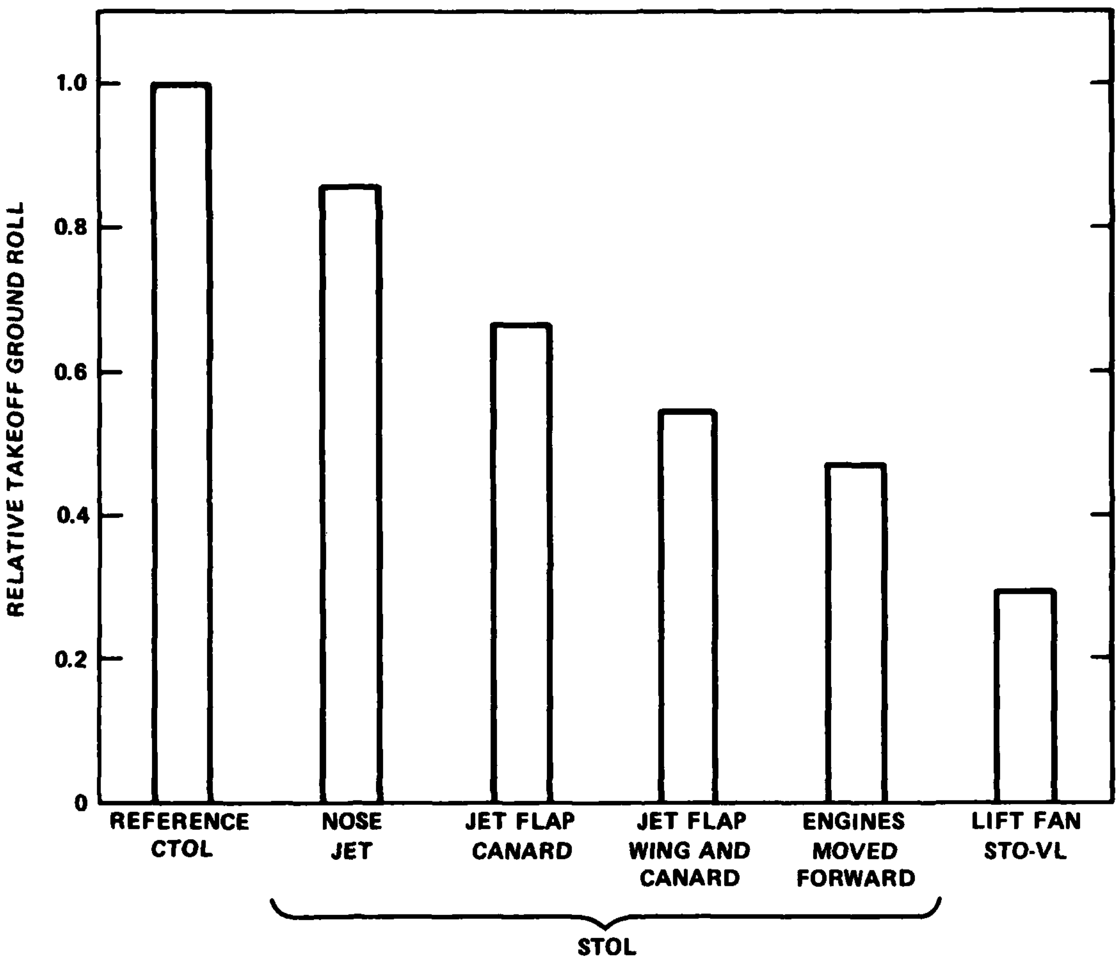


Figure 30 - Takeoff Distance Comparison

REFERENCES

1. Franciscus, L.C., "Turbine Bypass Engine - A New Supersonic Cruise Propulsion Concept," National Aeronautics and Space Administration, NASA Tech Memo 82608 (Jul 1981).

2. McCormick, B.W., Jr., "Aerodynamics of V/STOL Flight," Academic Press, New York (1967).

3. Stevens, V.C. et al., "Powered-Lift STOL Aircraft Shipboard Operations; A Comparison of Simulation, Land-Based and Sea Trial Results for the QSRA," American Institute of Aeronautics and Astronautics, AIAA-81-2480 (Nov 1981).

4. General Electric Company, "Conceptual Design Studies of Lift/Cruise Fans for Military Transports," NASA CR-1346.

5. "V/STOL Handling-Qualities Criteria," AGARD Report 577 (Dec 1970).

6. Kuhn, R.E., "An Engineering Method for Estimating the Induced Lift on V/STOL Aircraft Hovering In and Out of Ground Effect," Naval Air Development Center, NADC-80246-60 (Jan 1981).

7. Kuhn, R.E., "Design Concepts for Minimizing Hot-Gas Ingestion in V/STOL Aircraft," AIAA-81-1624 (Aug 1981).

8. Henderson, C. et al., "V/STOL Aerodynamics and Stability and Control Manual," Naval Air Development Center, NADC-80017-60, Section 2.2.2 (Jan 1980).

9. Hemmerly, R.A., "An Investigation of the Performance of a J52-P-8A Engine Operating Under the Influence of High Bleed Flow Extraction Rates," DTNSRDC Report ASED-387 (Aug 1977).

10. Lewis, G.M. and W.J. Lewis, "VSTOL Status from the Engine Technology Viewpoint," AIAA-81-2648 (Dec 1981).

INITIAL DISTRIBUTION

Copies	
1	OUSDR&E (ET)/R. Siewart
1	OASN (RE&S)/L.V. Schmidt
1	ONR/R. Whitehead (Code 432)
1	DARPA/R.W. Williams
1	USNA/Lib
3	NAVMAT 1 08 1 08D4 1 08T22
1	NAVPGSCOL/Lib
9	NAVAIRSYSCOM 1 AIR-03E/H. Andrews 1 AIR-320D/D. Kirkpatrick 1 AIR-5123F 1 AIR-528/F. O'Brimski 1 AIR-5284 1 AIR-530B 1 AIR-5301 1 AIR-53012 1 PMA-265/CAPT Weaver
1	NAVAIRPROPCEN/L. Palcza (PEV)
4	NAVAIRDEVCEN 1 Tech Lib 1 C. Mazza (3015) 1 W. Miller (IV3) 1 T. Brennen
12	DTIC
4	Wright-Patterson AFB 1 G.K. Richey/AFWAL/FS 1 W. Williams/AFWAL/FIMS 1 F. Krause/ASD/XRY/TAY 1 M. Stibich/AFWAL/POTX
1	NASA HDQ/J. Levine

Copies	
4	NASA Langley Res Cen 1 J. Campbell (287/J) 1 J. Chambers (355/J) 1 B. Henderson 1 J. Paulson
1	NASA Dryden Res Cen/T. Ayers
4	NASA Ames Res Cen 1 W. Deckert (FV) 1 D. Hickey (247 FSA/D) 1 D. Koenig (247-1/D) 1 P. Nelms (227-2/P)
1	NASA Lewis Res Cen/L. Gertsma
1	General Dynamics/Ft. Worth E. Snowden
2	General Electric/Cincinnati 1 William Willis 1 A.D. Beverage
1	Grumman Aerospace Corporation S.G. Kalemaris
1	Lockheed California/Burbank A.R. Yackle
1	Lockheed Georgia/H.S. Sweet
2	McDonnell Aircraft Co/St. Louis 1 T. Lacey 1 H. Ostroff
2	Northrop Corporation/ Aircraft Div. 1 O.A. Levi 1 P. Wooler
1	Pratt Whitney Corporation/ W. Palm Beach/W. Smith
2	Rockwell International/Columbus 1 P. Marshal 1 P. Bevilaqua

Copies	
1	Rolls Royce/Bristol, England W.J. Lewis
2	Vought Corporation 1 H. Driggers 1 D.B. Schoelerman
20	R.E. Kuhn, Inc.

CENTER DISTRIBUTION

Copies	Code	Name
1	1601	Aviation Program Officer
5	1606	S. de los Santos
10	5211.1	Reports Distribution
1	522.1	Unclassified Library (C)
1	522.2	Unclassified Library (A)
2	522.3	Aerodynamics Library

ILMED

8